The JOURNAL
OF THE
FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA

DEVOTED TO SCIENCE AND THE MECHANIC ARTS

VOL. CLXIX JANUARY, 1910 NO. 1

MECHANICAL & ENGINEERING SECTION

(*Stated meeting, held Thursday, December 2, 1909.*)

THE USE OF CONCRETE PILES.

BY
WM. F. HALL.

[This paper describes particular forms of concrete piles, their uses, and a review of the advantages of this application of reinforced concrete in effecting better construction and in reducing costs.]

THERE is one striking feature connected with the war that is being merrily waged around concrete: the unanimity of opinion existing between the opponents and adherents of the unbattled material as regards its availability for foundation construction. But, let it show its head above ground and immediately protests, ranging from mild-mannered objection all the way up the scale to vituperation, make themselves apparent from every quarter into which concrete has made inroads.

The bricklayer who scents the decrease of brickwork, the drain-tile and sewer-pipe man who no longer enjoys a monopoly, the brickmaker who contemplates his decreased output, they, and many others, all unite in the cry of "Down with concrete." This is exactly what engineers have been doing with it for centuries

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the Journal.]

217006

with the result that the tourist is enabled to pay homage to structures to-day that, but for their concrete foundations, would long ago have been mere unrecognizable heaps of masonry.

The man who first mixed water with stone and sand and tied them together with cement was the original conservator of natural resources. His puddling made it possible to give the house built on the sand the same stability as that founded on the rock. He devised the means of securing for structures immunity from time and the elements. The iron founders have erected statues to Vulcan. It is regrettable that the name of concrete's inventor should have escaped going down the ages.

As previously stated, concrete has been used as a foundation material for centuries. Of recent years, refinements of this application have come into use that are worthy of more than passing notice. The concrete bearing pile is supplanting its perishable wooden prototype. The concrete sheet pile is responsible for the construction of bulkheads and other marine structures that will be in existence centuries after their builders have been forgotten. The concrete caisson made possible the building of towering structures on the most treacherous kind of soil. Of these three the development and use of concrete bearing and sheet piles are perhaps the most interesting phases in the refinement of the application of concrete for foundation purposes.

The concrete caisson, while unequalled as a method of foundation construction for certain purposes, is limited almost entirely to conditions demanding almost the extreme of security due to either the nature of the soil or the load to be supported. Concrete bearing piles, however, are not subject to such severe demands and for that reason, largely enjoy a wider application than caissons. Concrete sheet piles, practically a new development in this country, are coming widely into use in place of the timber piles generally employed for bulkhead and other marine work.

The increasing use of concrete bearing piles, aside from the permanence that they add to any construction in which they are employed, possesses additional interest as a factor in the conservation of our forests. The use of wood piles has been one of the most prolific sources of deforestation. In the gradual decrease, if not elimination, of this condition, concrete piles will play an important part.

Hennebique, the French engineer, is generally credited with being the first to use reinforced concrete piles. The pile generally used by him is of what is known as the "made-up" type; that is, it is molded above ground and then driven like a wood pile. This type of concrete pile is widely employed in Europe where the increasing use of concrete piling is a direct result of the constantly rising price of wood piling.

A. A. Raymond was the first to awaken the American engineering world to the possibilities of concrete piling. The sys-

FIG. 1.

Preparing casings for Raymond concrete piles.

tem that he developed was a radical departure from Hennebique's method. Raymond piles which are of the "made in place" type, are made by driving a tapering sheet steel shell to refusal by means of a collapsible steel core, withdrawing the core and thereupon filling the shell which permanently remains in the ground, with concrete. The chief advantage of this method lies in the shell which protects the concrete until it has fully set. Furthermore, it assures a pile that can be easily inspected. The tapering shape of the piles causes them to act as wedges in entering the soil. The compacting of the soil by this

means causes a great increase in bearing power. For this reason much shorter piles may be used than when piles without a taper are driven. In addition, the steel core can be driven to refusal or a penetration not to be thought of with a wooden pile and the full bearing power of the soil developed beyond a doubt.

In 1903, Frank Shuman patented the Simplex system of concrete piling. While Simplex piles are molded in place there is this distinction, however, from the Raymond system: in the latter the shell permanently remains in the ground as a mold and protection for the setting concrete, while in the Simplex system the shell, as it is filled, is gradually withdrawn.

Since 1903 there has been a number of inventions in the concrete piling field in the United States. These new concrete piles have all been along the lines of Hennebique's "made-up" pile with the exception that instead of being vertically moulded as are Hennebique's piles, they are most of them horizontally moulded. The principal of these systems are the Gilbreth, the Chenoweth and the Cummings.

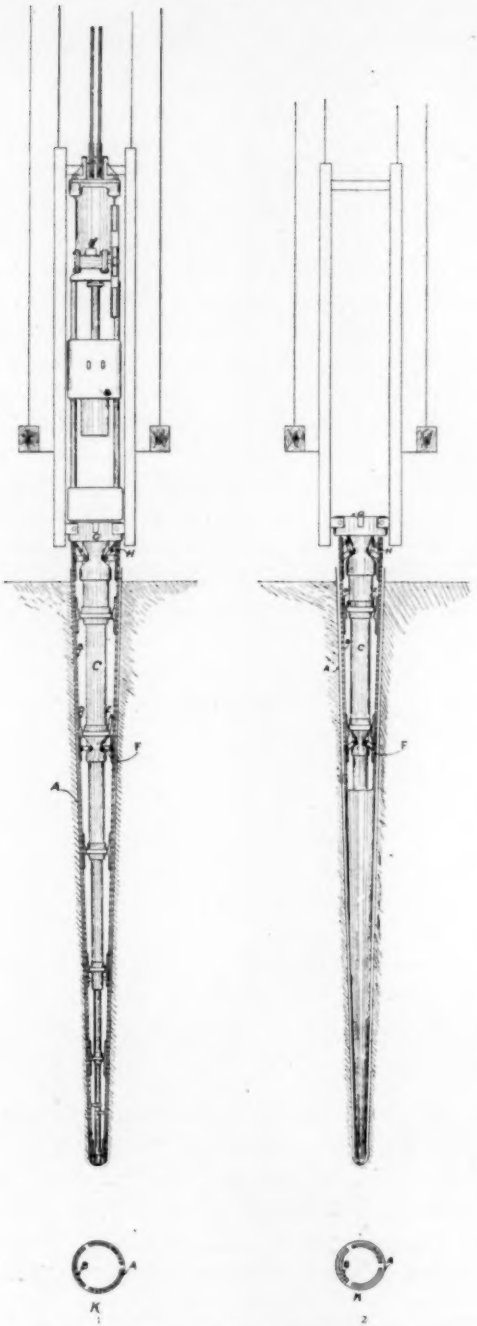
The Gilbreth pile is a corrugated tapering reinforced pile, with a hole running through the centre. The piles are cast in wooden forms and after curing, handled by an ordinary pile driver and jetted into place by running a 2-inch jet pipe through the hole in the centre of the pile. When the pile has been jetted nearly into place, the jet is removed and the pile driven to the desired penetration.

The Cummings pile is another type of made-up reinforced concrete pile, octagonal in section and of any length up to 60 ft. Except when driven to rock, this pile is made tapering in form to gain additional bearing power.

The Chenoweth pile is also a reinforced concrete pile that is cast before driving. This pile is round and is made without forms on a special apparatus and is reinforced with a steel pipe or rod in the centre, a coiled sheet of wire netting and longitudinal steel rods placed near the perimeter equal distance apart.

There is only one sure way known to-day to make wood piling practically permanent and that is to saw it off at a point below the water line or at a point at which the pile head will be continuously wet. This means that the footings or cappings resting on the piles and carrying the superstructure must go down below the permanent water line. Here

FIG. 2.



Sectional view of Raymond pile-core, showing collapsing and expanding device. (Steam-hammer in the leads resting upon the core). In this illustration the shell is driven and the core expanded.

is a point where the concrete pile effects a big saving, as it can be placed entirely independent of depth of the water line. It may be generally stated that if it should be necessary to lower the footings for wooden piles only 3 ft. on account of the water line, below the necessary depth of the cellar or basement, a great saving can be effected through the use of concrete piles. The lower the foundation footings are carried, the greater becomes the cost of these footings as well as the cost of excavation, shoring and pumping during the construction period.

The saving effected in these items through the use of concrete piles was strikingly illustrated during the construction of a new group of buildings at the U. S. Naval Academy, at Annapolis. The original appropriation for the academic group of buildings not being sufficient when the bids for these structures were opened, concrete piles were suggested to take the place of the wood piles called for in the specifications for the foundations. Investigation showed that by this substitution, the cost of the foundation could be reduced by about $27,000. The concrete piles were thereupon substituted. The itemized saving was as follows:

COMPARATIVE COST OF WOOD AND CONCRETE PILES.

Wood Piles.

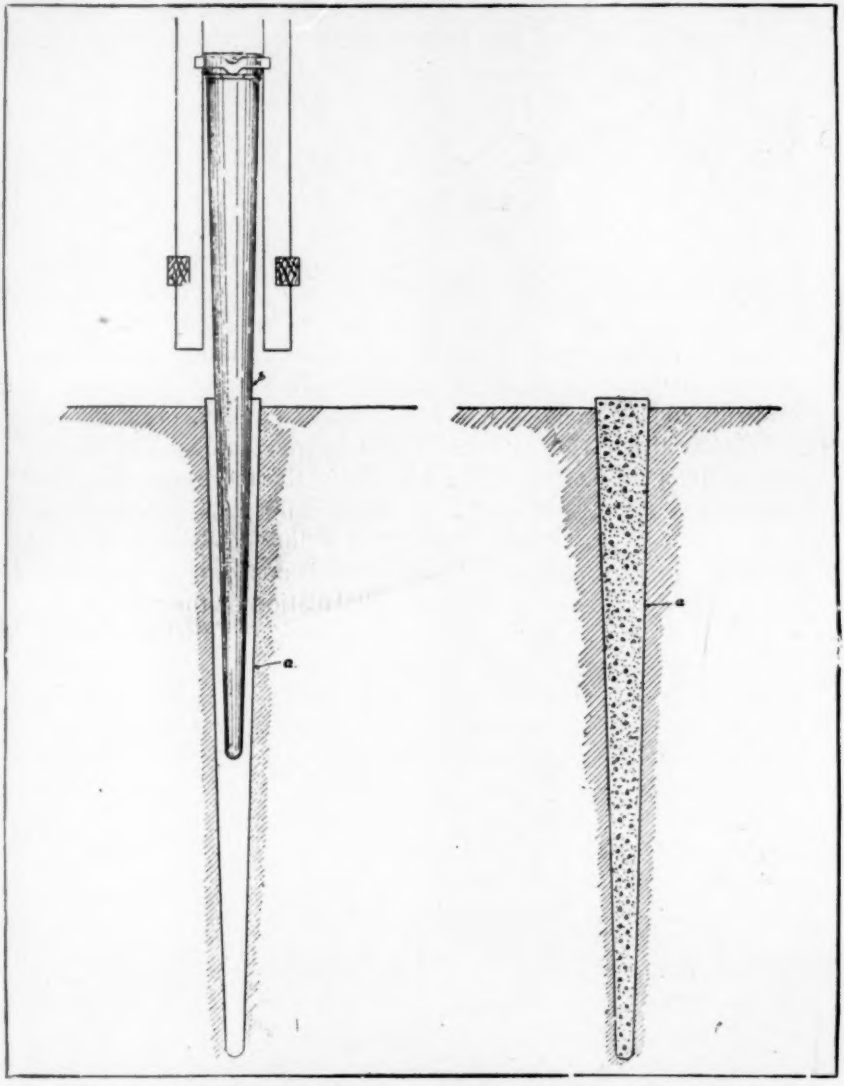
2193 piles, at $9.50	$20,835.50	
4542 cubic yards excavation, at 40 cents	1,816.80	
3250 cubic yards concrete, at $8.00	26,000.00	
5222 lb. I-beams, at 4 cents	208.88	
Shoring and pumping	4,000.00	
Total cost		$52,861.18

Concrete Piles.

855 piles, at $20.00	$17,100.00	
1038 cubic yards excavation, at 40 cents	415.00	
986 cubic yards concrete, at $8.00	7,888.00	
Shoring and pumping	.....	
Total cost		$25,403.00
Difference in cost		$27,458.18

Some time ago a vitrified duct conduit, about 1150 ft. long, was built at Long Island City for the Long Island Railroad. The soil across which the conduit line was to be built was originally a salt marsh and except where filling had been done for streets or to support railroad tracks, the soft quaking mud was about 30 ft. deep. Various supports were suggested, but the

FIG. 3.

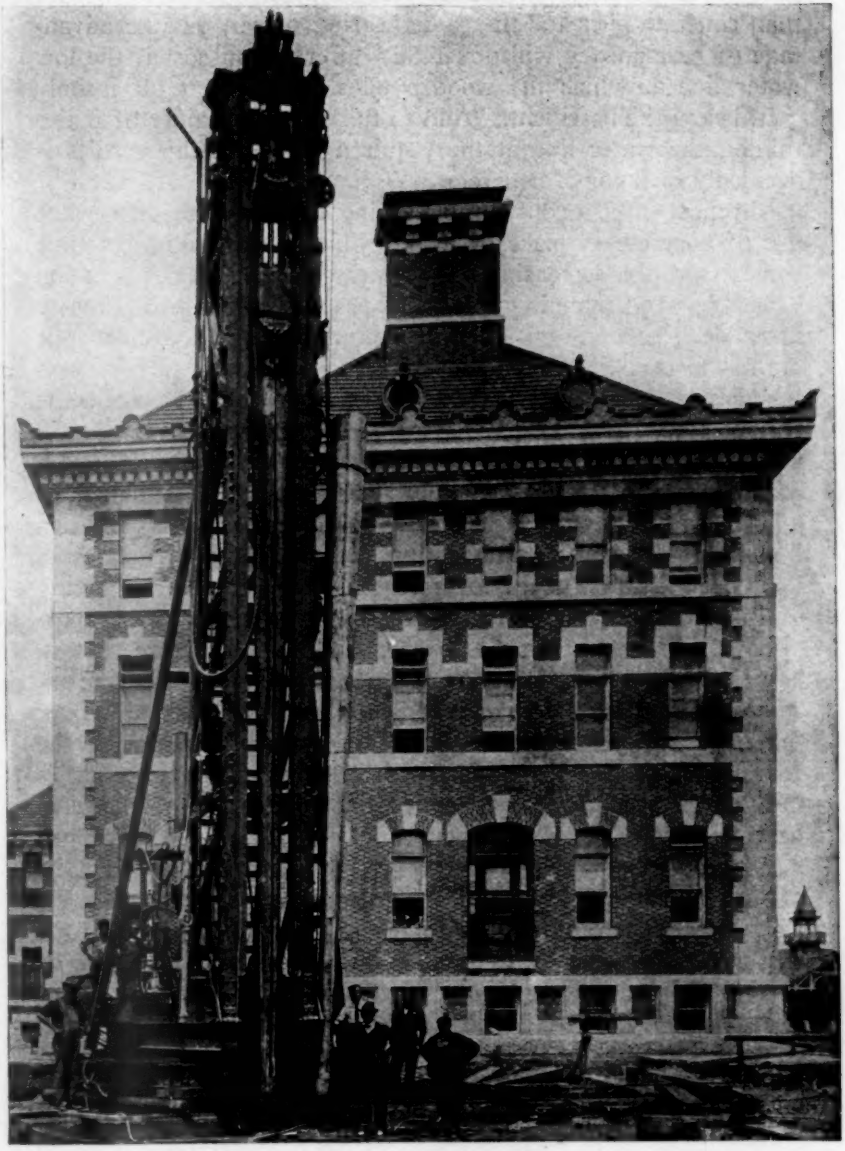


Partly and entirely completed Raymond concrete pile. To the left is shown a core collapsed and partly withdrawn from the shell. The shell permanently remains in the ground and forms a mold for the concrete. On the right is shown a completed Raymond concrete pile, without reinforcement.

choice finally lay between a support of plain concrete upon closely spaced wood piles, and one of reinforced concrete upon widely spaced concrete piles. The former would have required a trench 10 to 13 ft. deep in very wet muck in order to keep the tops of the piles below the probable permanent ground water level, and as it was desirable to locate the ducts as high above the present ground water level as possible, in order to avoid the difficulty and expense of drainage during construction, a large and expensive intermediate mass of concrete would have been required —the wood piles being, of course, permanent construction only when immersed. By using concrete piles the trench had to be but 6 ft. deep; the most difficult part of the excavation was thus avoided, the quantity of concrete reduced to a minimum, and the progress of the work facilitated accordingly.

With concrete piles, there is practically no excavation necessary below the basement level, except to give sufficient depth to the footings to distribute the load. Furthermore, there is no shoring or pumping. But the foregoing is not the only consideration that must be given to the water line. When once the wooden piles have been placed, cut off, and capped, then the water line must not drop below the assumed elevation or the wood piles will rot. This is a serious consideration and one that is attracting considerable interest, especially in large cities. The point is clearly indicated by the fact that contracts for concrete piles are constantly being secured under conditions where wood piles could be placed at the same or even lower cost and placed below the present water level, preference being given to concrete piles because of the fact that water levels are constantly changing in all cities, due to deeper sewers, freight and passenger subways and changing natural conditions. Even in New Orleans, where the city proper is below the level of the river, the new deep sewers have so changed the water level as to drain the tops of wooden piles. During a recent trip to New Orleans, one of the officials of a leading concrete pile concern, saw the foundations of a million dollar building in which wooden piles were used, where the new sewers had so lowered the water level as to expose piles in this foundation for 5 ft. of their length. It is a well known fact that in many of the buildings of Chicago, New York, St. Louis and other cities, water has been drained from the tops of wood piles and they have begun to decay with very serious results. This is a condition which makes wooden piling dear at any price and with permanency in view gives the preference to

FIG. 4.



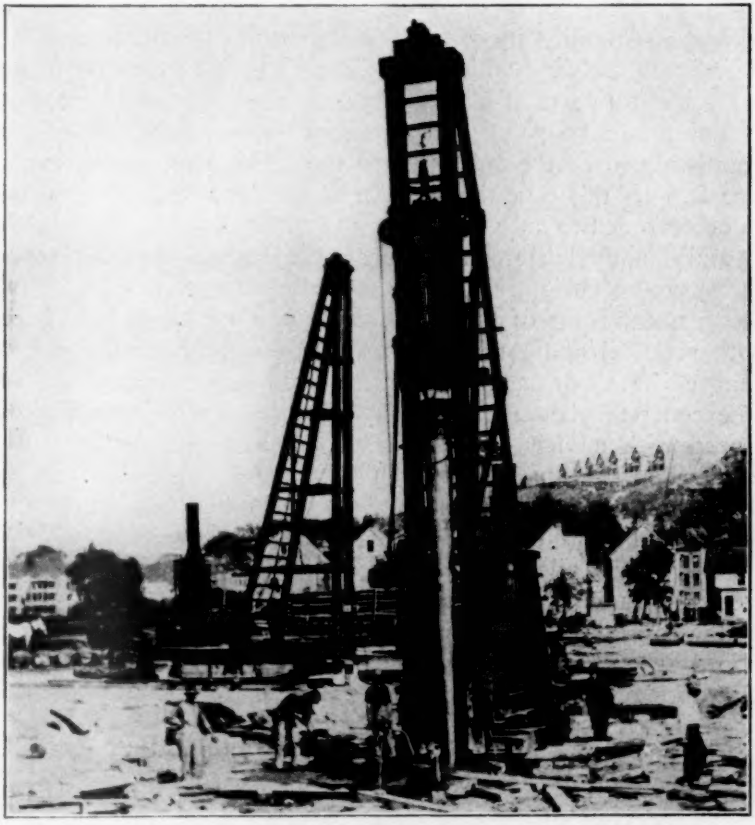
A Raymond pile-core and shell. The shell, which is shown to the right of the core, appears as it would be when in position in the soil.

concrete piles practically without any other consideration. Although assuming wooden piles to be about one-quarter cheaper than concrete piles for the same bearing power, yet the advantage of permanency will offset this difference in cost if the low water line at which the wooden piles must be cut off is only 3 ft. below the basement. Add to this the uncertainty of maintaining the water line at the required level and the verdict is decidedly in favor of concrete.

In most cases a considerable saving of time is effected in the use of concrete in place of wood piling. This saving in time comes from the decreasing of the excavation and the elimination of shoring and pumping. It takes practically the same time to assemble a concrete pile-driving plant as it does a wooden pile outfit and even if the made-up reinforced concrete pile is used, the piles can be made at once and the concrete allowed to set while the necessary excavation and assembling of plants goes on, or the first few piles driven can be shipped out of stock. In using concrete piles there are generally about one-half the number of piles to be driven and consequently much time is saved. When it comes to the capping and footing, the considerable reduction in their size by the use of the concrete pile, effects another big saving in time. This saving in the time of construction means a proportionate gain in rent on the finished building, a feature that is, however, often overlooked by prospective builders. In one instance the rent for the time saved by the use of concrete piles over the next available form of foundation actually paid for the foundation itself. The only disadvantage of concrete piling is in the slightly increased cost over wooden piles having the same bearing power. This, however, is only for the naked, uncapped pile. The advantages of concrete over wood piling are first, its permanency under any conditions, regardless of the nature of the soil; second, the saving in cost due to the great reduction in the size of the footings made possible by the use of fewer piles of greater bearing power; third, no concern as to the lower water line, thus saving considerable excavation and all shoring and pumping and finally the gain in building rental and saving of interest charges on investment due to the speed made possible by the substitution of concrete piles for piles of other types. It is thus apparent that in the total cost of a foundation, concrete piles afford the greatest economy in construction.

While concrete piles of all types are being used, 75 per cent. of them are of the " made-in-place-with-a-permanent-shell " type. Piles of this type have been found to be applicable wherever piling is necessary, with but a few exceptions. Their predominance

FIG. 5.



Driving a reinforced concrete pile.

is due to the assurance of the integrity of their shape afforded by the permanent steel shell; by their freedom from injury during driving or handling, a danger that all cast piles are subject to; by the speed with which they can be placed as compared to cast piles. They have been used by engineers and architects throughout the

country, by most of the railroad lines and very extensively by the Government, notably at the Immigrant Station at Ellis Island, New York.

In the reconstruction of the famous Atlantic City Boardwalk, concrete piles of the cast type were extensively used. The greater part of the walk was rebuilt in 1896, steel piling and caps being substituted for the wood piles previously employed. The moist, salt air of Atlantic City corrodes iron or steel with amazing rapidity and the fine sand which drifts like snow in every wind forms a most effective sand blast in removing any protective coating of paint. In 1907 it was decided to relocate a section of the boardwalk, near the Inlet, where the ocean had receded some 400 ft. By this time the steel under the old boardwalk had become corroded to such an extent as to make its safety doubtful. In addition, the blistered and scaly appearance of the metal, made the structure unsightly. Concrete had been used effectively for piling under some of the amusement piers and, therefore, from both practical and esthetic viewpoints, it appeared to those in charge of the work as the best material for the new construction. The concrete piles employed in this work were especially designed with a view to best meeting local conditions. As the boardwalk forms part of an architectural scheme for beautifying the city, it was essential that the piles be round and cylindrical, ornamental as well as useful. This factor precluded the use of the Raymond pile, and reinforced cast piles were thereupon selected. As no reliance was placed on the frictional resistance of the sand on the sides of the pile, the base was enlarged to afford a greater bearing area. It then seemed probable, in consideration of the greater area of the base, that the sand would not settle closely under the foot of the pile after it had been jetted into place causing subsequent settlement. While it is customary to drive piles to refusal after jetting is finished, in all cases where piling is driven into sand by means of a water jet, this obviously could not be done with a pile of the design used. It was therefore decided to prevent future settlement by compacting the sand under the pile in the following manner:

A length of 2½ in. pipe was cast into each pile, extending throughout its full length. The lower end was closed with a tapered wooden plug and the upper end with waste to prevent the entrance of concrete. After the pile had been placed the plug

was knocked out and sand rammed under the foot of the pile. As the pipe projected some 4 in. beyond the top of the pile it likewise served in suspending the pile vertically in the pile driver leads.

The piles were 16 in. in diameter and of two lengths, 28 ft.

FIG. 6.

Concrete piling in place.

and 32 ft. the shorter ones being used in the more protected portion of the walk and the longer ones in sections where the chances of erosion were greater. The elevation of the deck of the walk is 15 ft. above mean low water, the piles being driven 15 ft. or 19 ft. into the sand, depending upon the location. This precludes

any likelihood of the piles being disturbed by storms or the shifting of the beach from the action of wind and sea.

The walk is 41 ft. wide for a distance of 600 ft. and then narrows down to 21 ft. The wider section is supported on 4 pile bents, 20 ft. on centres, the piles being 10 ft. on centres, and the narrow section on two pile bents with the same spacing. The caps or girders are 8½ in. x 24 in. in section, with a 5 ft. cantilever at each end. The design is simple, but the proportion and general effect are pleasing.

The piles were moulded vertically, using a scaffold or trestle. This scaffold or trestle served as a bracing for the forms, a runway for distributing the concrete, and a substitute for a derrick or jin pole when lowering the piles. The moulds proper were made of sheet iron rolled into the proper cylindrical shape and screwed to wood braces. They were made in halves and bolted together with butt joints. Some difficulty was anticipated in handling the joints, since they were 32 ft. in length, but by careful design and building in the first place and careful handling thereafter, no trouble whatever was experienced in fitting them together or maintaining true alignment even after using each one some twelve times.

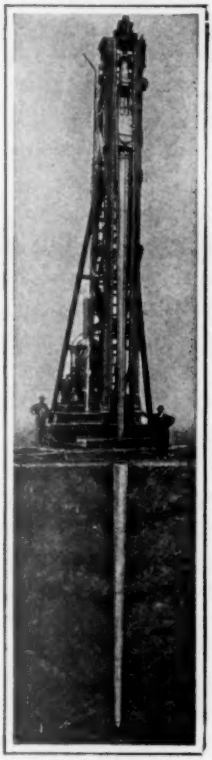
There were 90 spaces along the scaffold for moulds; 30 moulds were employed, one set in each third space. In rotation each mould occupied three different spaces, the mode of procedure being as follows: When the first column could be stripped, generally in two or three days, the mould was removed and swung into the next space, cleaned, greased, bolted together and filled. After two or three days the mould was again stripped, prepared as described, and set up in the third space. By the time the third pile was ready to strip, from nine to ten days after the first was poured, the first pile was hard enough to be removed. The mould could then be swung back into the first space and the sequence of operations was repeated.

The moulds were handled in an upright position using a pivoted lever. A short lever arm carried a chain and shackle which hooked into the top of the mould. Bearing down on the longer lever arm lifted the mould which was then swung to the next vacant space by rotating the lever on its pivot. This procedure was found capable and convenient.

To handle the cast piles was found a most difficult task. The

piles were 28 and 32 ft. long and weighed some 3½ tons and the reinforcement was not sufficient to keep the pile from breaking under its own bending weight. In fact when supported horizontally at two points half way between ends and middle the dead load stresses were far in excess of those considered safe.

FIG. 7.



View showing shell driven for Raymond concrete pile.

FIG. 8.

Photograph of over-driven wooden piles.

Some safe special method had to be devised for handling. The method adopted was as follows: Two rope slings were placed around the pile at points which would give the most even distribution of stresses, assuming the foot of the piles to be supported. Into these slings was hooked a wire cable with considerable slack which passed through a snatch block. The snatch block was hooked to one end of a tackle, the other end of which

was fastened to the top edge of the scaffold. The fall line from the tackle ran to a hand-winch on the ground. A strain was taken on the tackle and the pile pushed out from the scaffold at the top until supported by the tackle, its bottom hinging on a sill. The tackle was then slacked off with the winch, the snatch block travelling along the bight in the sling cable as the pile approached the horizontal. As the pile neared a horizontal position it was received on a wooden cradle with pillow blocks at each end. This cradle was tipped back into a flat car as the pile came to the horizontal, the slings were cast off and cradle and pile were slewed around parallel with the car track which ran alongside the scaffold. The car took the pile to a storage yard where it was rolled onto a skidway to cure.

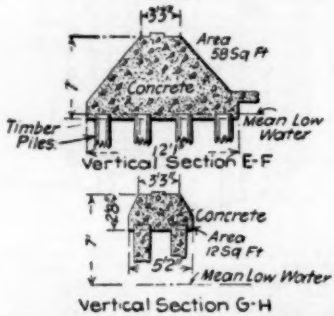
The narrow-gauge railway on which the cars ran passed along both sides of the scaffold by the storage yard and along the line of the walk. It proved to be a great labor saver. For moving the piles, two platform cars were fitted with turn-tables, making it possible to swing a pile to any angle from the track. This was found necessary both to aid in loading the columns on the cars and picking them up by the driver. A dump car was used to distribute material for the caps and girders. All lumber was moved on the flat cars.

The moulded piles were driven or sunk by a water jet. The round pile was rolled off the storage skids onto the cradle and then run to the driver. Here the slings, cable and snatch-block arrangement were adjusted and the pile upended. When vertical a hanger was secured into the end of the pipe projecting from the top of the pile, the purchase was hooked into this hanger and the slings were cast off, letting the pile hang vertical and free in the leads. The driver was then swung to bring the pile over the stake and sinking was begun, using two jets. The pile settled by its own weight through the sand, but when layers of clay were encountered it had to be churned until it broke through. When the pile had been sunk to the proper depth, and into the proper position the jet was pulled allowing the sand to settle around the pile, which it did in two or three minutes. Forty-eight hours after jetting the piles were settled in the following manner: A piece of 2 in. shafting 2 ft. longer than the pile was introduced into the central pipe and alternately raised and dropped, knocking out the wooden plug and compacting the sand under the foot

of the pile. This process was continued until the pile ceased to settle, from 2 to 6 in. of settlement usually occurring. When no further settlement was perceptible the pipe was filled with concrete and a cap moulded onto the column to the exact grade required.

At Baltimore, in the construction of the new municipal dock system, concrete bearing and sheet piles are among the most essential features of the work. After Piers 1, 2 and 3, the first three of the series of 6 had been completed, it was found that the cost of Piers 4, 5 and 6 if built of steel and concrete would be lower than that of the first three, which were built of timber and masonry. But, more important than that, traces of

FIG. 9.



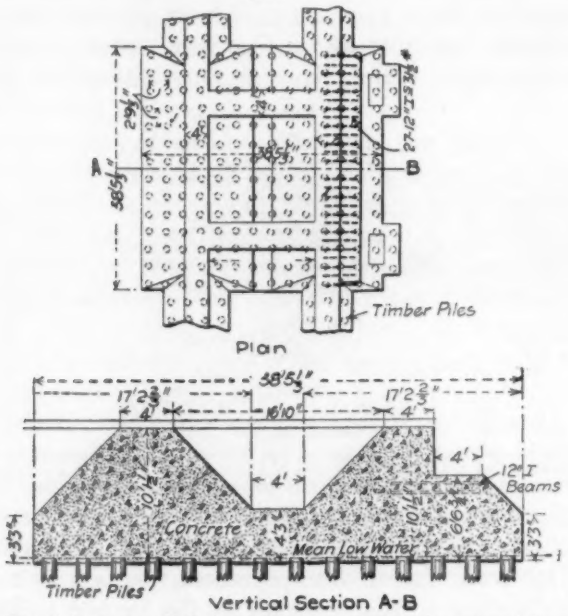
In the accompanying diagrams the section E-F shows the footing of the connection between the library and academic building as designed by Mr. Flagg for wood piles. Another sketch, G-H, in the diagram, shows the same section as built with concrete piles.

the teredo, a marine-boring animal exceedingly destructive to wood, had been discovered in the harbor. Only the polluted condition of the water has to date prevented this pest from making any great headway. Just as soon as the harbor is cleared of sewage, a matter of only a short time, it is expected that the teredo will make its appearance in great numbers with the result that all timber construction along the water-front, will be at the mercy of this wood-destroying vermin. For these reasons, Piers 4, 5 and 6 are being built of reinforced concrete.

The type of construction employed was developed by Baltimore's Harbor Engineer, Oscar F. Lackey, as a result of his investigations of European dock construction methods. Its many novel features, chief among which is the concrete sheet piling employed, have attracted the attention of engineers both here and abroad. One result has been the interest taken by concerns owning water-front property in more permanent dock construction

than is afforded by the antiquated timber and masonry type. Several of them already have under way concrete docks along the line of those being built at Baltimore. An idea of the magnitude of the operations at Baltimore is to be found in some of the items of construction: 14,000 cubic yards of concrete in cylinders; 25,000 lineal ft. of reinforced concrete tie piles; 42,000 sq. ft. of reinforced concrete floor and 220,000 surface ft. of reinforced concrete sheet piling.

FIG. 10.



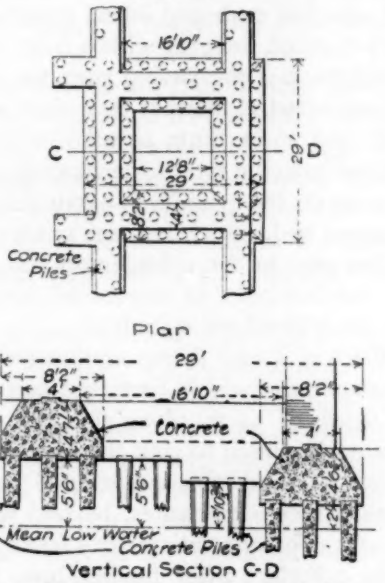
Plan and section of footings at U. S. Naval Academy as originally designed for wooden piles.

Piers 4, 5 and 6 consist of solid earth fill, retained on the sides and ends by reinforced concrete sheet pile walls penetrating below the dredged bottom of the slip and supported at their upper end by steel and concrete horizontal girders. These girders are anchored to reinforced concrete piles, made in place with a permanent steel shell, and are supported at their other ends on steel and concrete cylinders about 25 ft. apart on centres.

Pier 4 is 220 ft. wide and 978 ft. long and is designed to afford special provision for the bay craft, having a slip 70 ft. wide and 379 ft. long on the centre line at the outer end. Adjacent to this centre slip the steel and concrete cylinders support

the retaining walls on both sides of the main structure and are connected by transverse horizontal ties against the reinforced concrete sheet piles. Beyond the inner end of the centre slip, these ties are omitted and the thrust on the concrete sheet piles is resisted by a row of reinforced concrete piles 12½ ft. apart and 28 ft. back from the exterior face of the steel and concrete piers. At the outer end of Piers 4 and 6 there are special triangular steel and concrete corner cylinders, and the regular intermediate

FIG. 11.



Plan adopted using Raymond concrete piles.

cylinders are tied across, one to the other. Pier 5 is 1245 ft. long, 200 ft. wide at the shore end and 243 ft. wide at the outer end. Pier 6 is 1456 ft. long, 93 ft. wide at the shore end and 212 ft. wide at the river end, with three nearly right-angle offsets on one of the long sides, the projecting corners of which are protected by clusters of dolphin piles.

The pier wall has a vertical concrete face, consisting of a continuous line of reinforced concrete square-edge sheet piles, not interlocking, in 12-in. x 18-in. units, 27 ft. long, bevelled at the lower end. Four full-length ¾-in. vertical rods in the front surface and four ⅜-in. rods in the rear surface serve as

reinforcing. The lower ends of the piles penetrate from 24 ft. to 26 ft. below mean low water, and at the upper ends take bearing on the inner flanges of the horizontal lattice girder just above mean low water level. These girders are seated on the offset tops of the steel cylindrs 25 ft. apart on centres and take bearing with their outer flanges against the extended upper portion of the cylinder.

The face of the cylinder extends about 32 in. higher than the rear end and carries a continuous line of horizontal box girders supporting the concrete curb and wheel guard at the edge of the pier. The curb is made integral with a 6-in. concrete floor slab, 4 ft. wide, which carries the paving over the ends of the lattice girders and is supported at the rear on a short section of concrete wall, 6 in. thick and 20 in. high, parallel to the face of the pier, resting on and tied into the top of the concrete sheet piling. The bending movement on the cylinder is partly relieved by a horizontal tie at the upper end, which is some cases extends across the full width of the pier to the cylinder on the opposite side, and in other cases reaches only to reinforced concrete anchor piles about 30 ft. in the rear of the cylinders.

Work on Piers 4, 5 and 6 was commenced by wrecking the old piers and structures which formerly occupied the site, and dredging to a depth of 15 ft. along the faces of the piers, thus providing trenches in which to sink the cylinders and sheet piles. The soil consists of mud, fine gravel and sand to a depth of about 22 ft. below mean low water, beyond which there is very coarse gravel, which forms a satisfactory footing for the cylinders and piles. The cylinders after having been placed in position are filled with concrete placed under water with a drop-bottom bucket. After the cylinders are in place, the lattice girders, piles, anchor piles and reaction girders are set.

The sheet piles are cast at the site in ordinary wooden moulds, and after seasoning not less than 28 days they are delivered by a derrick scow to the leads of a floating pile driver. After being carefully aligned they are forced into the mud to a stable position by a water jet, and the weight of a 6000 lb. hammer seated on them.

After the completion of the sheet piling, the wall girders are set, and a 6 in. concrete wall is built parallel with it 3½ ft. away in the clear, which is practically an extension of the sheet piles which carry it between cylinders. The concrete floor is sup-

ported on the wall and on the parallel girder, and after its completion the face wall is built on it, the fender piles driven, and the back-fill, grading and paving completed.

A modification of the foregoing type of construction has been employed for the J. S. Young plant, Baltimore, a branch of the MacAndrews & Forbes Co., which is in turn owned by the American Tobacco Co., at the Deering plant of the International Harvester Co., Chicago, and, at the Sparrow's Point plant of the Maryland Steel Co. In the latter case provision is made in the construction to support a travelling ore conveyor along the bulkhead.

During the extension of the J. S. Young plant, more ground was required on the water side of the property for the erection of a new power house as well as for coal storage. As the present buildings comprising the Young plant were somewhat undermined through the deterioration of the wooden bulkheads and because it is the policy of the MacAndrews & Forbes Co. to make all its improvements permanent, all-concrete construction was decided upon.

The construction consists essentially of a series of tongue and grooved concrete sheet piles 18 in. wide and 12 in. thick and varying in length from 27 ft. to 36 ft. Superimposed on the sheet piles is a concrete girder connected, by means of reinforced concrete ties, with a continuous anchor beam dead-man, supported by occasional concrete piles. On account of the proximity of the bulkhead to some new buildings, it was found desirable, on certain portions of the bulkhead, to connect the ties with the building foundation. All of the buildings placed on this bulkhead are supported on concrete piles.

Part of the bulkhead was placed from the ground and part from the water, the fill behind being made after the bulkhead was in place. The depth of the water on the exterior space of the bulkhead varies from 12 ft. to 25 ft. One side of the bulkhead is used for the loading and unloading of coal. The type of construction employed increased the present available property of the Young plant by the area of a rectangle about 140 ft. x 200 ft.

The International Harvester Company, with its many miles of bulkheads along the Chicago River, is one of the first corporations to recognize the advantages of steel and concrete bulkhead

construction. The bulkhead is of essentially the same construction as that of the J. S. Young plant, except that cross buttress walls with concrete tie piles are used at 20 ft. intervals. From these buttress walls, reinforced concrete ties extend to cantilever concrete anchor dead-men supported on concrete piles.

The increased interest which is being shown by engineers throughout the country in concrete pile construction, for both foundations, and dock and pier work, is a matter of considerable gratification to those who have spent several years in bringing this permanent construction to the attention of the engineering profession. There is an increased desire on the part of the Federal, State and Municipal Government, as well as large corporations and people holding valuable property, to replace temporary construction heretofore used, with permanent construction, and there is every evidence that an increasing amount of this class of work will be done each year.

PRODUCTION OF SAND AND GRAVEL.

REPORT FOR 1908 BY GEOLOGICAL SURVEY.

The production of sand and gravel in the United States in 1908, as reported to the United States Geological Survey, was 37,216,044 short tons, valued at $13,270,032, a decrease of 4,635,874 tons in quantity and of $1,222,037 in value from the figures for 1907. Pennsylvania was the leading State in value, followed by Illinois, New York, and Ohio. The ordinary price of sand and gravel ranges from 8 cents to $1.50 a ton, the difference being mainly due to the variety of treatment to which the material is subjected after being excavated. Gravel for roofing or other special purposes may be valued as high as $3 a ton and some special kinds of glass sand bring from $7 to $20 a ton.

The production and value of the different grades are shown in the following table:

Sand and gravel produced in the United States in 1908.

	VALUE	QUANTITY (SHORT TONS)
Glass sand	1,093,533	$1,134,599
Moulding sand	1,980,677	1,342,802
Building sand	16,037,681	5,635,538
Fire sand	121,678	107,858
Engine sand	573,894	219,486
Furnace sand	339,523	190,023
Other sand	4,340,034	944,030
Gravel	12,729,004	3,695,696
	37,216,044	$13,270,032

These and other statistics are contained in a paper on glass sand, etc., published as an advance chapter from "Mineral resources of the United States, calendar year 1908." This paper may be had on application to the Director of the Geological Survey, Washington, D. C.

SECTION OF PHYSICS AND CHEMISTRY

(*Stated Meeting held Thursday, June* 10, 1909.)

A CRITICAL STUDY OF THE NATURAL CHANGES OCCURRING IN FATS AND OILS.*

BY

JOSEPH SAMUEL HEPBURN

A. M., Central High School of Philadelphia; M. S., University of Pennsylvania.

(Contribution from the Food Research Laboratory, Bureau of Chemistry, United States Department of Agriculture.)

(*Concluded from Vol. CLXVIII, page 456.*)

Clayton [74] describes an 18-year-old butter, which had been kept during the greater part of that time in the dark in a bottle with a broken, imperfectly fitting stopper. Hence ample opportunity for oxidation had existed. The butter had an offensive odor and was considerably discolored. The Hehner number of the butter fat had decreased during storage. The acidity had increased very considerably, while the saponification number was slightly higher than the maximum value given by Lewkowitsch.[75]

Papasogli [76] states that, when certain oils are exposed to the air and are permitted to come into contact with vegetable fibres, they rise in the fibres by capillary action according to their constitution and particularly according to the degree of their capacity for oxidation. The humidity of the atmosphere also exerts an influence upon their capillary action. Under the same conditions, the height—to which an oil rises in a definite time—is constant. The fluidity of the oils is lessened by high temperatures, since the oxidation of the oils then becomes greater. According to the more or less rapid oxidation capacity of the oils, at 40° C. in the air, Papasogli arranges them in the following series: olive, castor, colza, sesame, cotton seed, almond, resin, linseed, fish oil.

Swaving [77] stored samples of butter and of rendered butter

* Presented at the Seventh International Congress of Applied Chemistry, London, 1909.

fat in both open and closed vessels, in the sunlight and in the dark, for periods of 15 months and of 5 years. At the end of 15 months, the butter had a tallowy odor and was rancid; the Reichert-Meissl number of the specimens in both the open and closed vessels had decreased. Under the same conditions, the butter fat did not change in odor; its Reichert-Meissl number increased.

After storage for five years, the butter had become dark and mouldy; the Reichert-Meissl number of all the samples, including those kept in both open and closed vessels, in the sunlight and in the dark, had decreased; the decrease was more pronounced in those specimens kept in the open vessels. The color of the butter fat samples had changed to a yellowish-white, while an increase had occurred in the Reichert-Meissl number of all the specimens.

The statement is made that, in the case of the rendered butter fat, the glycerides are first hydrolyzed; the products of hydrolysis are then oxidized, and volatile fatty acids finally arise. The decomposition of butter itself is a process of oxidation, probably combined with bacterial action.

Browne [78] has made an extensive study of the rancidity of butter fat. He states that the three factors most active in the production of rancidity in fats are exposure to air, light and heat. Given sufficient time, decomposition may occur with the suppression of any one or even two of these elements, but it is most rapid when all three conditions are favorable. The research was confined entirely to those changes which butter fat underwent after its separation from all impurities. The color of the fat gradually became lighter until finally the entire mass was bleached. The odor and taste first became lard-like; then a pungent odor and a burning, unpleasant taste developed. The sample which originally was firm and solid in texture became granular and, after many months, changed to a semi-solid pasty mass.

Butter fat was analyzed when fresh, and at intervals of one week, one, two, four and eight months; the constants all showed progressive changes. A decided increase in acidity and in saponification and Reichert numbers occurred. The ester value showed a slight increase, and the iodine number a very marked decrease. Other samples of butter fat were submitted to

analysis when fresh, and after they had become rancid; beside the changes noted in the preceding experiment, it was observed that the acetyl value increased, while the Hehner number and glycerol content decreased. Elementary analysis showed that a rancid butter fat, which was two years old, contained lower percentages of carbon and hydrogen and a higher percentage of oxygen than did a fresh sample. The ratio of the total free acids to the free soluble acids, which, during the earlier stages of rancidity, was lower than the ratio of the total acids of butter fat to its total soluble acids, gradually approached the latter ratio. Both soluble and insoluble aldehydes were detected by means of Schiff's reagent. The decrease in iodine number, the presence of aldehydes and the absence of large quantities of free soluble acids during the earlier stages of rancidity led to the conclusion that the oleic acid, which is liberated, is first oxidized to aldehydes, and that these aldehydes become acids in the more advanced stages of rancidity. The presence of aldehydes is said to explain that rather strange phenomenon—the rise in the ester value. Aldehydes exert no influence upon the determination of the acid value; but, during the boiling with alcoholic potash in the determination of the saponification number, the aldehydes are partly changed into acids which neutralize a portion of the potash. Thus the value obtained for the saponification number is really a higher value than the true saponification number of the rancid fat. The ester or ether value, which is obtained by subtracting the acid value from the saponification number, thus appears to increase. The true ether value of a fat necessarily decreases as the glycerides are broken up.

The total glycerol content of butter fat decreased, when the fat became rancid; the presence of free glycerol in rancid fat could never be proved with certainty, although it may have been present in very slight quantities. The pungent odor of the rancid fat is attributed to the presence of a small amount of acrolein, a decomposition product of glycerol.

Certain physical constants of the fat also changed with the development of rancidity. The temperature of turbidity in the Crismer alcohol test became lower by several degrees. Both specific gravity and refractive index increased, but the specific refractive power decreased. The heat of combustion showed a marked decrease.

Browne considers that rancidity, like other forms of oxidation, is merely a slow process of combustion. He states that, since butter fat—as fresh as it can be obtained—has distinct acid and acetyl values, the process of rancidity has already begun in the fresh fat. While the ultimate products of oxidation would be carbon dioxide and water, this advanced stage is scarcely reached under ordinary conditions. "We are probably safe in saying that chemical change will not cease until all the glycerides are decomposed and the oleic acid is completely changed; whether or not other changes of a different order, such as the formation of paraffin bodies, may set in, is wholly a matter of conjecture."

Browne's statement, that but a small quantity of free soluble acids is present during the earlier stages of rancidity, confirms the statement of Bondzynski and Rufi,[79] who found that free volatile or soluble fatty acids of butter could be detected only in a rather advanced stage of decomposition. They ascribe rancidity to the presence of free insoluble fatty acids, both saturated and unsaturated.

Hanus [12] found that, as butter became rancid, the glycerides of the insoluble fatty acids were decomposed far more rapidly than the glycerides of the acids of lower molecular weight. Under the influence of light and air, butter gradually lost its yellow color and became like lard; a rancid smell and a sharp, tallowy taste developed. The acidity and saponification number of the butter fat increased; and the iodine number decreased, while the Reichert-Meissl number underwent no essential change. Hanus concludes that unsaturated acids form lactones under the influence of the air.

Hall [80] mentions that the saponification number of a pure, rendered mutton tallow which had been kept for 10 years, had experienced a considerable increase during that time.

Jakimenko [81] ascribes the changes which fats undergo in the process of rancidity to the action of air and light; the temperature also plays a part. As a fat becomes rancid, the acidity increases, while the quantity of unsaturated compounds decreases. When fats were exposed to air, from which carbon dioxide and moisture had been removed, they became less rancid than fats which were exposed to the atmosphere.

Lewkowitsch [82] kept a sample of cacao butter in a sealed bottle

for 10 years. It did not become rancid, and the acidity increased but little. Six samples of cacao butter were exposed to the action of air, moisture and sunlight for three to four days. All became white and acquired a decidedly rancid, repulsive odor and a nauseous taste; but one of the samples showed a higher acidity; in the other specimens the acidity had even decreased. The same six samples were kept for a fortnight, then again exposed for three to four days. A slight rise in acidity occurred. Although taste and smell left no doubts of rancidity, the chemical indices—viz., acid value, saponification value and Reichert-Meissl number—gave no clue of the enormous change wrought by the exposure. One of the rancid cacao butters responded to Schiff's reagent and to the silver nitrate test for aldehydes, but failed to respond to the m-phenylene diamine test; instead of assuming a deeper color, the diamine solution became colorless.

Sherman and Snell [83] studied the relation of the heat of combustion to the specific gravity of various fatty oils. They concluded that oxidation resulting from exposure to air decreases the heat of combustion in inverse ratio to the increase in specific gravity. Hence it is to be inferred that the oxygen is taken up by direct addition and without essential change in the volume of the oil.

Sherman and Falk [84] permitted samples of various oils to stand for several months upon a laboratory shelf which was frequently exposed to direct sunlight. The samples were kept in uncorked bottles which were loosely covered to exclude dust, and were occasionally shaken. Since all the conditions of the rate of oxidation could not be controlled, the exposure and shaking were not the same for all the samples. The constants of the exposed samples were compared with those of duplicate samples, from the same packages, which had been kept in a dark closet, in well-filled, air-tight containers. The constants of many of the oils had been determined before the beginning of the experiment; these values in all cases agreed closely with those of the samples which had been protected from air and light, hence the latter samples had undergone no appreciable change. In the exposed samples of olive, lard, cotton seed, maize, poppy seed, seal and linseed oils, the iodine number was lower and the specific gravity higher than in the protected samples. The exposed oils produced a greater rise in temperature in the Maumene temperature reac-

tion, and were characterized by higher acidity and Reichert-Meissl number, although the changes in the last two constants were so slight and irregular that they could not account for the changes in the other constants. The conclusion was reached that, since the increase in specific gravity was produced by the formation of hydroxyl groups at the unsaturated linkages, that increase was directly proportional to the decrease in the iodine number.

Lewkowitsch[85] states that oils and fats will remain unchanged for practically an indefinite period of time, provided light and moisture be excluded. Since it is exceedingly difficult to exclude the last traces of moisture in stored oils and fats, a slight hydrolysis of the glycerides may occur during storage. This liberation of fatty acids in the presence of moisture is due to the action of enzymes, which occur in animal and vegetable tissues and accompany the expressed or rendered fats and oils.

Rancidity is produced by the direct oxidation of the free fatty acids of fats and oils by the atmospheric oxygen in the presence of light.

Winckel[86] kept oleic acid for periods of two and three weeks. Both the iodine number and acid value of the acid decreased; it gained in weight, and gave a red color with phloroglucin and hydrochloric acid. When the exposed fat was distilled in a current of steam, the distillate formed a color with m-phenylene diamine solution.

Samples of oleic acid and of glycerol were stored at 40° to 50° for several weeks. At the end of that period, the acid was neutralized with potassium hydroxide and then distilled in a current of steam; the distillate gave the characteristic aldehyde reactions with the following reagents: phloroglucin hydrochloric acid, fuchsin sulphurous acid, m-phenylene diamine hydrochloride, and ammoniacal silver nitrate. On the other hand, no aldehydes were formed in the glycerol during the exposure.

Winckel concludes that the aldehydes, which develop in fats and oils during the process of rancidity, are derived from the unsaturated acids and not from the glycerol. Oleic acid undergoes autopolymerization and auto-oxidation, as a result of which polymerization products and an oxy fatty acid are formed; and, finally, the oleic acid is partially split into compounds of lower carbon content, including volatile acids and aldehydes. Strong rancidity is simply an advanced stage in the oxidation of the

fats and oils. While bacteria and enzymes may aid in the production of rancidity, nevertheless absorption of oxygen by the unsaturated acids explains all the changes which are observed in fats when the latter are exposed to the action of light or heat, or of the atmosphere.

Legler [87] has proved the presence of active oxygen in oxidized fats, especially oxidized lard. He proceeds as follows: Ten c.c. of water are warmed in a test-tube; an equal volume of the molten fat is added, then several drops of a solution of neutral lead acetate and of ammonia water, and the mixture is vigorously shaken. If the fat contains active oxygen, the mixture assumes a pale yellow to a deep orange-brown color in consequence of the formation of hydrated lead peroxide. The intensity of the color depends upon the quality of active oxygen present in the fat. Pure cotton seed oil, which contains no active oxygen, does not respond to the test; however, samples of the oxidized oil, as well as oxidized lards, give a positive reaction. Cotton seed oil and American lard are said to be especially capable of absorbing oxygen; the absorbed oxygen may be removed completely by moderate heating. According to their oxygen content, oxidized lards produce a more or less strong reduction of silver nitrate solution (Becchi's test).

According to Walker [49] after pure cocoanut oil has been exposed to light and air for several months, it assumes a slight but noticeably acrid taste and odor, without any marked increase in acidity. Such oils contain aldehydes and active oxygen. The aldehydes cause the rancid oil to react with fuchsin sulphurous acid—Schiff's reagent—with the production of a bluish color faintly tinged with red. Since a mixture of either acrolein or oenanthol with cocoanut oil gives a red color with Schiff's reagent, the rancid oil must contain aldehydes other than acrolein and oenanthol. Under certain conditions Schiff's reagent may form a blue color with glycerol aldehyde, but this aldehyde has no odor. In a few rancid oils, the red tint predominated in the aldehyde test; these oils failed to respond to the test for active oxygen. Active oxygen was detected in all the samples which gave a blue color in the aldehyde test. These samples liberated iodine from potassium iodide, and gave a blue color to potassium iodide-starch paper. The test for active oxygen was carried out as follows: Potassium iodide-starch paper was saturated

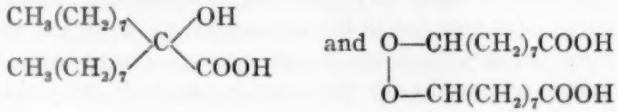
with the rancid oil, and a drop of 10 per cent. acetic acid was placed upon the paper which was then covered by a bell jar to protect it from laboratory fumes. A blue ring formed about the acetic acid in the course of one to five hours. Fresh oils failed to form a ring, even when they were permitted to act upon the test paper for 25 hours. Oils, which responded to the potassium iodide-starch paper test, also formed yellow hydrated lead peroxide in Legler's test, although the latter test was not so delicate. Peroxides, and usually aldehydes, were not present in commercial oils, and those oils which had been submitted purposely to the action of organisms.

Walker considers that the rancidity of pure cocoanut oil is a process of oxidation by the air in the presence of light, and depends largely upon the area of the exposed surface of the oil. The oxidation occurs in several stages; fatty acids are converted into oxy acids which then form lactones. Lactones are changed into per-acids, and these per-acids oxidize the glycerol to an aldehyde. The slight increase in the acidity of pure cocoanut oil on long standing is due to hydrolysis, caused by heat and moisture.

The action of ozone upon oleic acid and the fats has recently engaged the attention of chemists. Molinari and Soncini [88] investigated the ozonide of oleic acid. Oleic acid, or its solution in acetic acid, absorbs ozone from ozonized air with the formation of an ozonide, the formula of which is

$$CH_3(CH_2)_7CH - CH(CH_2)_7COOH$$
$$\quad\quad\quad

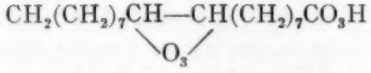
at higher temperatures. The decomposition occurs best when the ozonide reacts with sodium hydroxide solution. A small quantity of gas and of the pleasant-smelling, unsaponifiable compound arises; the chief products of the decomposition are four organic acids, nonylic and azelaic acids, and two acids the formulæ of which follow:



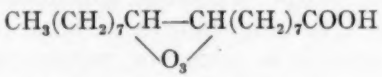
Of the two formulæ, the first corresponds to di-n-octyl hydroxy acetic acid. Three molecules of the ozonide decompose and give rise to one molecule of each of the four acids. During the decomposition of the ozonide, no reaction for aldehydes or hydrogen peroxide could be obtained.

Ozone was permitted to act upon linseed, maize, castor, olive, rape and other oils. All the oils absorbed ozone in greater or lesser quantity, just as they absorb iodine.

Harries and Thieme [89] studied both the ozonide and ozonide-peroxide of oleic acid. The solution of dry oleic acid in chloroform absorbed ozone from ozonized air, with the formation of the ozonide-peroxide, the formula of which is:



Hence, one molecule of oleic acid combined with four oxygen atoms. The ozonide-peroxide was a thick syrup. It was washed with water and a solution of sodium bicarbonate, then dissolved in ether. When the ether was evaporated, there remained a less viscous liquid, the normal ozonide



The wash waters gave a strong reaction for hydrogen peroxide, into which the fourth oxygen atom of the ozonide-peroxide had been converted during the washing. The normal ozonide was also prepared by passing ozonized air into the solution of oleic

acid in glacial acetic acid, then diluting with water and neutralizing with sodium bicarbonate.

The ozonide-peroxide is a water-clear, almost vitreous liquid, which detonates but weakly when heated on platinum foil. Upon standing with slight quantities of water, it gradually decomposes with the separation of solid azelaic acid.

The normal ozonide is a colorless, viscous oil, from which slight traces of water cause the separation of solid azelaic acid. It detonates but weakly when heated upon platinum foil. When the ozonide is prepared from the ozonide-peroxide the yield varies considerably, for frequently the ozonide splits into azelaic acid and nonylic aldehyde or acid during the washing.

Both the ozonide and the ozonide-peroxide have the same solubilities with a single exception. The ozonide-peroxide dissolves in acetic ester, from which it is precipitated by the addition of petroleum ether. On the other hand, the normal ozonide dissolves in acetic ester, but is not precipitated by the addition of petroleum ether. If the same quantity of the ozonide and ozonide-peroxide be boiled with water for the same period of time, both will give a reaction for hydrogen peroxide, but the reaction will be far more intense in the case of the ozonide-peroxide. Both ozonide and ozonide-peroxide give cleavage products with water, including azelaic and nonylic acids, nonylic aldehyde, and azelaic acid half aldehyde.

Molinari and Fenaroli [90] prepared the ozonide of triolein. The solution of olein in petroleum hexane absorbed ozone with the formation of an ozonide; a molecule of ozone was added at each of the three double bonds which occur in triolein. The product had a pale yellow color, was transparent and gelatinous, and was difficultly soluble in ether. It decomposed completely at 120° to 130°.

Upon fractional treatment with potassium hydroxide, the crude ozonide yielded a purer ozonide, which was soluble in ether, acetic acid, benzol and chloroform. The theoretic molecular weight of the ozonide is 1029; by means of the cryoscopic method, using benzol as the solvent, a molecular weight of 1017 was obtained. The ozonide reacts with alcoholic potash to form azelaic and nonylic acids, and an acid with the formula $C_{18}H_{36}O_3$; it also liberates iodine from alcoholic potassium iodide solution. When the ozonide is boiled with water, hydro-

gen peroxide is not formed. The crude ozonide is considered to be a polymer of the pure ozonide.

Ryan and Marshall[91] studied the influence of air, oxygen, and nitrogen upon both sterilized and unsterilized samples of olive oil, some of which were exposed to the light while others were kept in the dark. Samples of the oil, 20 c.c. in volume, were placed in Pasteur pipette flasks of 100 c.c. capacity, which were then filled with moist oxygen or nitrogen, and sealed at both ends. Before some of the flasks were filled with gas, they and their contents were sterilized by immersion in boiling water for 15 minutes on each of three consecutive days. During this period both tubes of each flask were plugged with sterilized absorbent cotton. During sterilization, a decrease in the saponification number and a slight decrease in the iodine number occurred.

After a storage of 13 months, the flasks were opened and the contents analyzed. In those samples which had been sealed in an atmosphere consisting exclusively of oxygen, both the sterilized and unsterilized specimens which had been exposed to diffuse sunlight—as well as the sterilized specimen kept in darkness—had a lower iodine number and a higher saponification number than the oil in the fresh condition. The same changes had taken place in the unsterilized sample, which had been kept in the dark, but the sealed tube of the flask had become broken at an unknown time during the storage. All the specimens, which had been surrounded by an atmosphere of oxygen, had become very rancid—in several cases the color had somewhat changed.

All the samples, sterilized and unsterilized, which had been sealed in an atmosphere of nitrogen for 13 months, including those exposed to diffuse sunlight and those kept in the dark, showed practically no change in the iodine number, while the saponification number had increased. None of these samples became rancid; a faint fading in color was produced by the diffuse sunlight.

The influence of air upon olive oil was also studied. When the sterilized oil was kept in diffuse sunlight for three weeks, in Pasteur pipette flasks, which were plugged with sterile cotton, it became colorless and rancid; the iodine number decreased, while the saponification number showed a very slight increase.

Unsterilized oil was stored in cotton-stoppered test tubes for 13 months;—in direct sunlight, diffuse sunlight and the dark. In all three cases the iodine number diminished, while the saponification number became greater. In all the samples, rancidity developed, and they were also somewhat bleached.

The fresh oil was preserved at room temperature in diffuse sunlight, in a blue glass stoppered bottle, and analyzed after the lapse of three weeks and of 13 months. An air space of about 100 c.c. existed in the bottle above the surface of the oil. After three weeks, a slight fall in the iodine number, and a slight rise in the saponification number had occurred, the oil was not rancid. After 13 months both the iodine number and the saponification number had decreased, and the oil had become strongly rancid. During the entire experiment the oil did not lose its color.

Gill [92] made a series of experiments upon an olive oil to determine the effect of the atmosphere upon the iodine number of the oil under various conditions of exposure. After a current of air had been drawn through the oil eight hours per day for seven weeks, practically no change had occurred in the iodine number. Exposure of the oil in a beaker for seven weeks had no effect upon the iodine absorption. When the oil was heated for two hours to 120° in an open dish, a very slight decrease in the iodine number occurred.

After the oil had been emulsified by the method usually used in preparing "top" dressing (use of ammonia and soda), and had been recovered with ether, the iodine number was unchanged. Such emulsified oil was sprinkled upon absorbent cotton, or upon fat-free woollen "tops," and was extracted after a period of seven and five weeks, respectively. In both cases the iodine number had diminished; the decrease was progressive, the oil exposed for seven weeks having a considerably lower iodine absorption than the oil exposed for but five weeks. Gill concludes that olive oil changes but little upon exposure to air or heat, unless spread out in a finely divided condition.

V. Sénkowski [93] has described a specimen of oleic acid which had been stored for over 19 years. According to its iodine number, the sample contained 32.1 per cent. of oleic acid, and according to its ester value, 8.3 per cent. of stearolactone. Since the specimen had a high acetyl ester value and practically no true acetyl value, it was decided that, during the process of acetyliza-

tion, hydroxystearic acid was converted into stearolactone. After allowing for the quantity of stearolactone, present as such in the specimen, the quantity of hydroxystearic acid, calculated from the acetyl ester value, was found to be 20.6 per cent. It was concluded that the remaining 39 per cent. of the specimen consisted chiefly of hydroxystearic acid, which, converted into lactone by the process of acetylization, was regenerated by the water during the washing of the acetylated fat. This conclusion was confirmed by elementary analysis of the specimen. A slight quantity of "acids of another composition" was also present. V. Sénkowski is of the opinion that oleic acid is first transformed into stearolactone to which he gives the formula:

$$C_nH_{2n+1}CH_2CHC_nH_{2n}CO$$
$$\qquad\qquad\quad |\qquad\quad\ |$$
$$\qquad\qquad\quad O\text{——}\quad\ |$$

The lactone absorbs water and changes into the corresponding hydroxy acid. Thus the oxygen content of oleic acid increases upon long standing.

The gases which form the atmosphere of the earth are able to produce changes in the fats and oils at ordinary temperatures. Moisture gives rise to an hydrolysis of the glycerides, especially if aided by the action of light or the presence of a lipase. Carbon dioxide causes a tallowy taste and an increase in acidity. Nitrogen has no action upon fats; this is also true of hydrogen at ordinary temperatures. Oxygen calls forth many changes in properties of the fats; it increases the specific gravity, melting point and refractive index, acidity and saponification number and, at times, the Reichert-Meissl number. A greater rise in temperature in the Maumene test may be obtained, while the temperature of turbidity in both the Valenta and Crismer tests becomes lower by several degrees. The iodine and Hehner numbers, heat of combustion and, at times, the specific refractive power decrease. A rancid smell and taste develop; the glycerol is usually oxidized; acids of lower carbon content belonging to both the fatty and oxalic series form, as do also hydroxy acids and lactones. The occurrence of aldehydes in such fats and oils is very common; oenanthol has been identified in rancid olive oil; the presence of acrolein and of glycerol aldehyde in rancid fats and oils has been suggested. Active oxygen has been detected

CHANGES PRODUCED IN FATS, OILS AND ESTERS BY ATMOSPHERIC GASES.

Gas	Fat, Oil or Ester	Acidity	Saponification Number	Hehner Number	Iodine Number	Reichert-Meissl Number	Index of Refraction	Specific Gravity	Acetyl Number Hydroxy-acids	Aldehydes	Other Constants	Investigator	Number
Air	Esters	+	:	:	:	:	:	:	:	:		Berthelot	60
Air	Oils and tallow	+	+	:	:	:	:	:	:	:		Gröger	63
Air	Lard	+	:	:	:	:	:	:	:	:		Ritsert	64
Carbon dioxide	Lard	+	:	:	:	:	:	:	:	:		Ritsert	64
Oxygen	Lard	+	:	:	:	:	:	:	:	:		Ritsert	64
Air	Vegetable oils	+	:	:	:	:	:	+	:	:	Maumene+	Ballantyne	65
Air	Fish oil	+	:	:	:	:	:	+	:	:	Valenta−		
Air	Cotton seed	+	:	:	:	:	:	:	+	:		Fahrion	67
Air	Linseed	+	:	:	:	:	:	:	+	:			
Air	Cod liver	+	:	:	:	:	:	:	+	:		Fahrion	69
Air	Lard	+	:	:	:	+	+	:	+	:	Melting point+	Spaeth	58 70
Air	Olive oil	+	+	+	+	+	+	+	+	+		Scala	72
	Lard												
	Butter fat												
Air	Butter fat	+	++	:	+	+	:	:	:	+		Mjöen	73
Air	Butter fat	+	++	:	+	:	:	:	:	:		Clayton	74
Air	Butter	:	:	:	:	+	:	:	:	:		Swaving	77
Air	Butter fat	:	:	:	:	+	:	:	:	:		Swaving	77
Air	Butter fat	+	+	+	+	+	+	+	+	+	Ester value+	Browne	78
											Crismer−		
											Heat of combustion−		
Air	Tallow	:	+	:	:	:	:	:	:	:		Hall	80
Air	Oils	:	:	:	:	:	:	++	:	:	Heat of combustion−	Sherman and Snell	83
Air	Oils	+	:	:	:	+	:	:	:	:	Maumene+	Sherman and Falk	84
Air	Lard	:	:	:	:	:	:	:	:	:	Active oxygen present	Legler	87
Air	Cocoanut oil	:	++	:	:	:	:	:	:	+	Active oxygen present	Walker	49
Air	Olive oil	:	:	:	:	:	:	:	:	:		Ryan and Marshall	91
Oxygen	Olive oil	:	:	:	:	:	:	:	:	:		Ryan and Marshall	91
Air	Olive oil	:	:	:	:	:	:	:	:	:		Gill	92

in rancid fats and oils. Many of these changes may be explained by the oxidation of the insoluble fatty acids. Absorption of an oil in wool, cotton or chamois leather causes the oxidation to proceed at a far more rapid rate than in bulk. Under the influence of the atmosphere, all the acids, which are present as glycerides, take part in the formation of free acid. Ozone forms an ozonide and an ozonide-peroxide with oleic acid, and an ozonide with olein.

EXPLANATION OF THE TABLE.

Under "gas" is given the gas; under "fat, oil or ester" the compound upon which that gas was permitted to act.

A sign in the columns of fat-constants signifies that the gas caused an increase (+) or a decrease (—) in the value of that constant.

A sign + in the column headed "aldehydes" signifies that aldehydes were detected in the fat or oil after the gas had acted upon it.

Under "other constants" are listed changes in the constants less commonly determined.

The columns "investigator" and "number" give the name of the investigator and the number assigned to his paper in the appended bibliography.

THE ACTION OF LIGHT UPON FATS AND OILS.

Fats and oils are exceedingly sensitive to the action of light. Direct sunlight, diffuse daylight and artificial light all call forth changes in their chemical and physical properties.

Scala [94] exposed fats, like lard and olive oil, which contain almost no soluble, volatile, fatty acid, to sunlight. After 15 days had elapsed, the fats contained volatile acids but the taste had not yet become rancid.

Goldberg and Huggenberg [95] studied the influence of direct sunlight upon the period of thawing of various vegetable oils. This constant of an oil was determined as follows: 100 grammes of the oil, contained in a glass-stoppered bottle, were placed for two hours in a freezing mixture, composed of ice and salt. The initial temperature of the mixture was —20° C., the final temperature usually —16° C. The period of thawing included the

time which elapsed from the removal of the bottle from the freezing mixture, until the oil was completely melted.

Samples of olive, rape, castor and bleached olive oils were exposed to direct sunlight for a period of six weeks. The period of thawing for each oil was determined at the beginning of the experiment and after the lapse of two, and of six weeks.

The time required for thawing became progressively less as the period of illumination increased. But slight changes occurred in the refractive index of each oil, while the iodine number was practically unaltered at the end of six weeks. Olive oil, stored for several years with exclusion of air and light, had the same period of thawing as fresh oil.

Roloff [96] discusses the action of light from the viewpoint of physical chemistry. Physical effects of light, in contrast to chemical effects of light, are those in which light acts upon chemical elements or compounds without changing the material composition of the individual molecules. The light exerts itself in changing the element or compound into another modification or isomeride, which is distinguished from the original either by the arrangement of the atoms in the individual molecules, or by the polymerization of the molecules.

The rearrangement of the atoms in the molecule always consists of the transformation of a maleic form into its isomeride of the fumaric type; the two halves of the molecule, which are united by a double bond, turn opposite to each other, and a rotation of 180° thus occurs. As far as measurements exist, the original or maleic form is always more soluble and has lower melting and boiling points. Transformation into the fumaric form occurs with the evolution of heat; hence a more stable compound is produced.

In the study of photopolymerization, several constants must be considered. If B be the polymer of A, then B must have lower vapor pressure, lower specific heat, and higher melting and boiling points than A. Moreover B must be less soluble than A; be formed exothermically from A, and pass back into A upon heating. B also has a greater molecular weight than A. Unsaturated hydrocarbons and their derivatives possess the power to form polymers under the influence of light.

The following explanation of the mechanism of the physical effects of light is offered. The effect of light must be other than

imparting a purely mechanical motion to the molecules, for heat, which imparts such a violent motion, usually reverses the physical effect of light. Moreover, the physical action of light occurs upon unsaturated compounds. Von Helmholtz [97] has devised an electro-magnetic theory concerning color-dispersion, in which he assumes that molecules possess electric polarity, and that the electro-magnetic light waves, by their different effect upon the two poles, cause either an elongation or a shortening of the electric axis of the molecule. Roloff bases his theory of the physical action of light upon this assumption of von Helmholtz. By the change in length of the electric axis of the molecule, a rupture of the union or bond, which holds the molecule together, may occur. If the bond be double (or triple), one bond may open, while the other alone holds the molecule together. The opened double bond may then unite with a similar open bond of another molecule, whereupon polymerization occurs; or a rotation of the molecule may take place with the formation of a geometric isomeride.

Reinmann,[14] in his second paper upon the rancidity of butter, states that, after butter had been exposed to direct sunlight twelve hours daily for a month, it had slightly increased in acidity, and became tallowy and non-edible, but not rancid.

Jensen,[15] in his second paper upon the rancidity of butter, describes the effect of light upon samples of sterile butter fat, which were kept for two and a half months in sterile glass vessels. One sample was exposed to sunlight; after one week had passed it had become perfectly white; at the end of the period of storage, its aroma resembled that of decomposed tallow, rather than rancid butter. The acidity had increased and the iodine number decreased, while a strong reaction for aldehydes was obtained. A second sample was kept in weak, diffuse light at 35° C. It became lighter in color, but not entirely white. The taste became disagreeable, the acidity increased, the iodine number decreased, and a reaction of aldehydes was obtained, but the changes were less pronounced than those in the specimen which had been exposed to sunlight. A third sample was kept in the dark at room temperature; it remained unchanged in taste, acidity and iodine number. Jensen concludes that light, like heat, makes the fat especially reactive toward oxygen.

Lewkowitsch [98] states: "The present state of our knowledge

does not justify, therefore, the assumption that light alone, to the exclusion of air and moisture, is capable of effecting a chemical change in glycerides."

Kreis [99] describes color reactions for oils, which have been exposed to the action of light for some time. Even if such oils have not been noticeably bleached, yet they respond to these tests. Fresh sesame oil gives no color, when shaken with hydrochloric acid of specific gravity 1.19; upon shaking a mixture of a fat or oil which has been exposed to the light, fresh sesame oil and hydrochloric acid, a green color is formed. If an oil which has been exposed to the light be shaken with hydrochloric acid of specific gravity 1.19 and a 1 per cent. ethereal solution of resorcin, a violet color arises; under similar conditions, phloroglucin gives a red, and napthoresorcin a green color; these colors recall the aniline colors both by their beauty and permanency. Pyrogallol gives a beautiful blue color, which reaches its full intensity only after it has stood for some time. Hydroxyhydraquinone also produces a color.

Winckel [100] has used the phloroglucin and hydrochloric acid reagent of Kreis in a study of both rancid fats and fats altered by the action of light. Since all rancid fats, with the exception of rancid butter fat, and all fats, which had been decomposed by the action of light, including butter fat, responded to the test, he concluded that the two processes of decomposition are analogous but not identical. In both processes, compounds are formed, which react in the same manner with the reagent of Kreis. After fats and oils have been exposed to sunlight for a short period of time, they give a red color with phloroglucin and hydrochloric acid, although they have not become rancid to smell and taste. Chemically pure oleic acid, which does not respond to the test, will give a color after it has been exposed to the air for several days, or to the sun for several hours. Winckel considers that the oleic acid of the fat or oil is either oxidized or polymerized; the compound, thus formed, responding to the test. He states that the best proof of rancidity is obtained by organoleptic tests, since phloroglucin and hydrochloric acid do not react with rancid butter, and form far too delicate a test to be applied to other fats and oils.

According to Winckel all those samples of fats and oils, which respond to Kreis's reagent, also react with vanillin and hydro-

chloric acid with the formation of a red color. Butter fat forms the single exception to the rule; the proteins or the ferments of butter and not the butter fat itself, give the color.

Droste [29] studied the influence of artificial light and of the Röntgen rays upon olive oil. Bottles of 20 c.c. capacity were filled with the oil and tightly corked, then placed upon a glass shelf beneath a bell jar of milk glass. The temperature of the oils depended upon the distance of the bottles from the incandescent gas burner, which served as a source of light; it varied between 70° and 40° C. However, the higher temperature was found to be without essential influence upon the oil. After the oil had been exposed to the light for 21 hours, it had scarcely altered. After an exposure of 86 hours in the case of the one oil, and of 126 hours in the case of the other, the samples had become almost colorless, and had assumed a tallowy odor and a tallowy, sharp, but not harsh, taste. The iodine number had decreased, while both the acidity and quantity of free, water-soluble acids, had increased. The formation of a solid elaidin was greatly retarded.

A mixture of 20 c.c. olive oil and 5 c.c. water was exposed to air and the gas light for three days, during which time it was frequently shaken. The oil was drawn off by means of a tap funnel, and then filtered. It was almost colorless, had a tallowy odor and a slightly harsh taste, still recalling that of olives. The elaidin test was affected but little, while a slight increase in the acidity and a slight decrease in the iodine number had occurred.

Röntgen rays were permitted to act for 140 minutes upon olive oil. The formation of a solid elaidin was greatly retarded. The chief change in the constants was a slight decrease in the iodine number. During all these experiments the refractive index remained unchanged. Droste states that light produces a molecular rearrangement of the glycerides.

If fats and oils be exposed to the action of light, long before rancidity may be detected organoleptically they will respond to certain color forming reagents, such as a mixture of concentrated hydrochloric acid and one of the following phenols—resorcin, phloroglucin, napthoresorcin, pyrogallol, hydroxyhydraquinone and vanillin. At times, fats and oils—which have been exposed to the action of light—respond to the tests for aldehydes, com-

pounds which occur in a certain variety of rancidity. Light bleaches fats, produces a tallowy odor and an unpleasant taste, increases the acidity and decreases the iodine number and the value of the constant known as the "period of thawing." It causes photopolymerization, and also changes unsaturated compounds of the maleic type into their geometric isomerides of the fumaric type. Artificial light likewise gives rise to changes in the oils; it produces a tallowy odor and taste, increases the acidity, decreases the iodine number and retards the formation of a solid elaidin. The Röntgen rays exert an exceedingly slight influence upon fats and oils. Of the changes described above, the molecular rearrangements are probably produced by the unaided action of light. The changes of a chemical nature are probably due to the action of atmospheric agencies and are greatly accelerated by the influence of light.

CHANGES IN FATS AND OILS UPON EXPOSURE TO HEAT OR COLD.

Heat, like light, produces changes in fats and oils. These changes may be due either to molecular rearrangement or to decomposition of the glycerides. Recent studies show that both chickens and butter undergo chemical decomposition during cold storage.

Spaeth [101] states that, if butter fat and fats in general be strongly heated, the saponification number and refractive index increase, while the iodine number decreases. The Reichert-Meissl number is changed but little, if at all. Both heated and rancid butter fat lose their color and odor, and become white and tallowy. When strongly rancid fats are heated, the acidity and saponification number of the heated fat are lower than in the unheated rancid fat, but higher than in the same fat in the fresh condition. Volatile acids have escaped during the heating. The iodine number is lower and the refractive index higher in the heated rancid fat than in either the unheated rancid fat or the same fat in the fresh condition.

In his second paper upon the rancidity of butter, Jensen [15] describes an experiment concerning the action of heat upon pure butter fat. After a sample of butter fat had been heated for 24 hours, in the dark, at 95° to 98° C., it gained in weight, the acidity increased, and the iodine number decreased. Oxidation of the fat had occurred.

Lewkowitsch [102] states: "The natural fats can be heated to a temperature of about 200° or 250° C. without material change, provided prolonged contact with air is avoided."

Fahrion [103] heated oleic acid and the acids of linseed oil for six hours, at a temperature between 110° and 120° C., the iodine number and acid value decreased in both cases, while a small quantity of a neutral compound was formed. The sample of oleic acid lost in weight during the heating. Polymerization and autoxydation produced a decrease in iodine number and acid value. The products of autoxydation split off water, causing a loss in weight and the formation of neutral bodies, possibly lactones.

Halfpaap [104] recently suggested that the work of Brühl and Lewkowitsch offers an explanation of the occurrence of abnormally high refractive indices in lards, which have a normal iodine number. Brühl [105] states that all those compounds, in which unsaturated atom-groups—their nature and number may be any desired one—occur, possess normal molecular refraction (to be calculated from the saturation formula), and also approximately normal molecular dispersion, provided that these groups are "isolated"; that is, are not directly linked to a second unsaturated complex. An example of this class of compounds is diallyl. Compounds, which contain directly adjacent or "conjugated" groups, give "exaltations," or abnormally high values, in respect to molecular refraction and, to a still greater degree, in respect to molecular dispersion. Isodiallyl belongs to this class of compounds. Moreover, the carboxyl group $-C\overset{=O}{\underset{-OH}{}}$ and the group —CH = CH— are unsaturated groups, since they contain double bonds.

The following formulæ of oleic and iso-oleic acids were derived by Lewkowitsch [106] and are given by Benedikt-Ulzer.[107]

Oleic acid $CH_3(CH_2)_{13}CH=CHCH_2COOH$

Iso-oleic acid $CH_3(CH_2)_{14}CH=CHCOOH$

Halfpaap draws attention to the fact that in oleic acid the two unsaturated groups, carboxyl and — CH = CH —, are "isolated," and the acid should have a normal refractive index, while, in iso-oleic acid, the two unsaturated groups are "conjugated"

and the acid should have an abnormally high refractive index. He suggests that the abnormally high refractive index of those samples of lard, which have a normal iodine number, is due to the presence of iso-oleic acid, which possibly has been formed from normal oleic acid by a shifting of the double bond, produced by the heat during the rendering of the lard.

Droste [29] heated a sample of olive oil, in the dark with access of air, for 35 hours at 80° to 90° C. The properties of the oil were not changed. Exposure of olive oil to a mean temperature of — 10° C. (maximum — 4° C., minimum — 16° C.) for ten days had no effect upon either the chemical or physical properties of the oil.

The changes undergone by the fat during the cold storage of chickens has recently been studied by Pennington,[108] from whose paper the following abstract has been made. Chickens of the Plymouth Rock breed were studied. The fat of a fresh chicken "is normally a light canary yellow, exceedingly transparent, and with no hint of green." The cold storage fowls were kept at 13° to 15° F. (— 10.55° to — 9.44° C.), and thawed in water. After storage for 10 months, the fat was "distinctly a deeper yellow" and "becoming opaque." A chicken which had been in storage for two years showed that the bands of fat upon the inner part of the thigh were shrunken and "of a deep brown-orange color." The chicken had an odor recalling that of acrolein. In the course of a further study [109] of chickens of various breeds, the constants of the fat of fresh birds, and of birds which had been in cold storage for periods of 14 months, 2 and 4 years, were determined. The acidity of the fat of the cold-stored fowls was always higher, and the other constants differed from the normal values as found in fresh chickens.

Lafar [16] kept fresh butter at a temperature of 0° to + 1° C. for 37 days. The bacterial count decreased, then slightly increased. The butter assumed a tallowy taste, but otherwise was unaltered.

Sayer, Rahn and Farrand recently studied the influence of cold storage upon butter. The results of their research have been published in both English [110] and German.[111] The acidity showed progressive increase in those samples of butter which were kept in cold storage at a temperature of 5° C. They

usually became rancid and contained moulds. Those butters, which were stored at lower temperatures, from —5° to —10° C., showed practically no change in acidity. However, during the manufacture of several samples, the creamery conditions had been very poor, and those specimens, which contained *Oidium lactis* in considerable quantity, were characterized by increased acidity. After butter had been in cold storage for several months, it frequently became "rancid," "aged" or "tallowy" in flavor. Volatile esters were found in only one sample, which had been stored for nine months. Usually samples of butter, which became rancid during cold storage, did not increase in acidity. The investigators are undecided as to the cause of the development of rancidity during cold storage. Either fat, lactose or protein, by its decomposition, may give rise to rancidity with its accompanying bad odor and taste.

Heat usually increases the acidity, saponification number and refractive index of a fat, and decreases the iodine number. Oxidation and polymerization occur. It may also cause a shifting of double bonds so that two "isolated groups" may become "conjugated groups," whereupon a rise in refractive index is produced.

During cold storage of chickens, marked changes occur both in the physical appearance of the fat and in its constants. Butter in cold storage may become rancid, but those who studied this butter are not certain which constituent decomposes and gives rise to the rancidity.

RANCIDITY AND ACIDITY.

Formerly the acidity of a fat was looked upon as the direct measure of its rancidity. Ballantyne [65] found that in some varieties of oil, rancidity developed before the acidity increased, while in other varieties the acidity became greater before rancidity appeared. Besana [112] noted that some samples of butter became rancid, although the acidity of their fat was lower than that of the fat of edible butter. The work of von Raumer [113] upon butter showed that rancidity could not be measured by the determination of the acidity. Sendtner [7] declares that acidity and rancidity are distinct and independent phenomena. He states that the rancidity of butter, and of butter fat, is best determined by organoleptic tests, among which may be mentioned the tallowy

odor and the bleaching of the color upon that surface which has been exposed to the light. Schmid [114] has devised an excellent classification for decomposed fats; he distinguishes between acid fats, rancid fats, and fats both acid and rancid. In acid fats, the free fatty acids are abnormally high, but the free glycerol is unchanged. In rancid fats, the quantity of free fatty acids is not high, but the free glycerol has been oxidized partly or entirely to aldehydes and ketones. Fats which are both rancid and acid contain a large quantity of free fatty acids, as well as oxidation products of glycerol.

The work of Spaeth [58] and of Thum,[71] as well as that of Hanus,[115] shows that the saturated and unsaturated acids, which are insoluble in water, are liberated in the same ratio in which they occur in the fresh fat. Browne [78] and Bondzynski and Rufi [79] have noticed that free soluble acids occur in but slight quantities during the earlier stages of the decomposition of butter. Hanus [115] states that the hydrolysis of the glycerides of the volatile acids of butter fat, as compared with the hydrolysis of the glycerides of both the saturated and unsaturated acids, proceeds in the same ratio in which the different acids occur in the butter. Weigmann and Backe [116] found free, non-volatile fatty-acids in ripe cheese; they attribute the formation of these acids to a decomposition of the fat during the ripening of the cheese. Although several investigators have found practically no free glycerol in decomposed fat, Gantter [117] found 2.1 per cent. of free glycerol in a tallow which had become "in high degree rancid." The tallow contained a normal quantity of total fatty acids (90.8 per cent.) and of total glycerol (8.7 per cent.). The tallow had the following composition:

Fatty acids in glycerides	61.9 per cent.
Fatty acids in free state	28.9 per cent.
Glycerol in glycerides	6.6 per cent.
Glycerol in free state	2.1 per cent.

Geitel [118] states that he has frequently noted the presence of considerable quantities of free glycerol in palm oil, which has undergone an hydrolysis (in the barrel) in the absence of light and air.

The acidity of a fat or oil is usually determined by titration of the free fatty acids, after they have been dissolved in a suitable solvent, usually ethyl alcohol. This procedure, including

the use of a standard aqueous solution of sodium hydroxide and the application of phenolphthalein as the indicator, forms the provisional method of the Association of Official Agricultural Chemists,[119] and is also recommended by Walker,[120] Archbutt,[121] Allen [122] and Lewkowitsch.[123] Lewkowitsch states that ethyl alcohol may be replaced by methyl alcohol, amyl alcohol, or a mixture of ethyl alcohol and ether. Deering [124] uses a standard alcoholic potash solution for the titration. The acidity of a fat or oil is usually expressed as acid degree Burstyn,[125] acid degree Koettstorfer,[23] acid value or percentage of free acid as oleic.[119] An acidity of 1° Burstyn signifies that the free acids which are contained in 100 c.c. of an oil require for their neutralization 1 c.c. of normal solution of sodium or potassium hydroxide. An acidity of 1° Koettstorfer signifies that the free acids, which are contained in 100 grammes of a fat or oil, require for their neutralization 1 c.c. of normal solution of sodium or potassium hydroxide. The acid value specifies the number of milligrammes of potassium hydroxide, which are required to neutralize the free acids contained in one gramme of a fat or oil. The percentage of free acid as oleic or, as it is sometimes expressed, the percentage of free oleic acid is calculated upon the assumption that free oleic acid alone causes the acidity of fats and oils.

Gad [126] noticed that a drop of an acid fat possesses the power of forming an emulsion spontaneously upon mere contact with an alkaline liquid. At times the drop of fat showed a curious amœba-like motion during the formation of the emulsion. Rachford [127] has based upon this property of spontaneous emulsion, a method for the quantitative determination of the acidity of fats and oils. A ¼ per cent. solution of sodium carbonate was applied as the alkaline fluid; the maximum spontaneous emulsion was then given by oils which contained 5.5 per cent. of free acid. A larger quantity of free acid produced an incomplete emulsion. If an oil contained more than 5.5 per cent. of free acid, by a series of successive approximations, neutral oil was added to the acid oil, until the latter contained just 5.5 per cent. of free acid, and produced a maximum spontaneous emulsion. The acidity of the undiluted acid fat was then calculated from the degree of dilution. The method was used in studying the hydrolysis of oils, which was produced by the action of pancreatic juice. It may be mentioned that Gröger [128] has devised a

method for the separation of the neutral glycerides from the free acids of a fat or oil.

The rancidity of a fat or oil may be due to the presence of either aldehydes or volatile esters. Nagle [129] states that rancid fats contain the following substances in variable quantities:

(*a*) Free fatty acids, both saturated and unsaturated.

(*b*) Hydroxy acids of the fatty acid series.

(*c*) Lactones and anhydrides of fatty acids.

(*d*) Alcohols, *e.g.*, butyl, amyl, caproyl and capryl alcohols.

(*e*) Esters of unsaturated, of saturated and of hydroxy acids of the fatty acid series, with higher and sometimes also polyhydric alcohols, *e.g.*, butyl, caproyl, capryl alcohol and glycol.

(*f*) Aldehydes, both saturated and unsaturated, *e.g.*, butyric, caproic and caprylic aldehydes, acrolein, and oenanthol.

(*g*) Acetals or esters of the above aldehydes and alcohols.

(*h*) Terpenes.

Nagle gives a method for the purification or refining of rancid fats and oils, which contain the above products of decomposition. Lewkowitsch [130] points out that the chief fault in Nagle's paper lies in the fact that he does not state how the presence of the various compounds was proved.

Marx [131] suggests that aldehydes are the real cause of rancidity. In a second paper [132] he shows that aldehydes are actually present in rancid fats.

Schmid [114] introduced the following test for the presence of aldehydes and ketones in fats and oils. A mixture of 20 grammes of the fat or oil and 100 c.c. of water is distilled in a current of steam. The distillate is received by a 100 c.c. graduated flask, into which 5 c.c. of a freshly prepared 1 per cent. solution of m-phenylene diamine hydrochloride have been introduced. Schmid states that, in his experiments, the distinction in color between the distillates from fresh fats and those from rancid fats was similar to the distinction in color between pure water and sewage water, as obtained by the Nessler test. The distillates from fresh fats showed a faint trace of yellowish color, while the distillates from rancid fats were characterized by a color varying between a strong yellow and a yellow-brown. A decided difference was observed in the color produced by fresh fat and rancid fat, when 20 grammes of the molten fat were shaken with 1 c.c. of a 1 per cent. solution of m-phenylene diamine hydrochloride.

Mayrhofer [133] states that every butter contains constituents which are volatile in steam and partake of the nature of aldehydes or ketones. They reduce ammoniacal silver solution, and form colors with fuchsin sulphurous acid and m-phenylene diamine. He attempted to determine the quantity of these compounds, which were present in the distillate, by oxidation with potassium permanganate in alkaline solution, by precipitation of silver from an ammoniacal solution and by the intensity of the color with fuchsin sulphurous acid. The results obtained by oxidation with permanganate in alkaline solution were the most satisfactory. Rancid butter and that manufactured from sour cream always gave a reduction with ammoniacal silver solution.

Bianchi [134] recommends that fuchsin sulphurous acid be prepared by mixing the following reagents in the given order:

30 c.c. of an 0.1 per cent. solution of fuchsin.
20 c.c. of sodium bisulphite solution of 34° Baume.
200 c.c. of water.
3 c.c. of sulphuric acid of 66° Baume.

Ten c.c. of the reagent and 2 c.c. of the oil are mixed; the maximum color is produced within thirty minutes. Oils, which are not rancid, either produce no color or give an exceedingly slight tint. Rancid oils give rise to a violet color in the layer of oil; oils which are particularly rancid also produce a slight coloration in the aqueous layer. The test may be applied to molten fats.

Amthor [11] has devised a method for the measurement of the rancidity, when that phenomenon is caused by the presence of volatile esters. Ten grammes of butter are distilled in a current of steam until 500 c.c. of distillate have collected. The distillate is exactly neutralized with $\frac{N}{10}$ alkaline hydroxide; 50 c.c. of $\frac{N}{10}$ hydroxide are added and the solution is heated for 30 minutes beneath a reflux condenser, in order to saponify the esters. The excess of alkali is then titrated, and the quantity of esters calculated. Of course, the preliminary neutralization measures the quantity of free volatile acids.

CONCLUSION.

In all probability, organisms are unable to subsist upon absolutely pure and sweet fats and oils. If even slight quantities of nitrogenous compounds, either organic or inorganic, be present in a fat, they serve as a source of nutriment for organisms, which

then thrive upon the fat and give rise to changes in its composition. Organisms are apparently able to subsist upon rancid fats.

The bacteria, which decompose fat, are always aerobes and, almost invariably, liquefiers. One group of bacteria merely splits the glycerides and thus increases the acidity of the fat. A second group first hydrolyzes the glycerides, then consumes the liberated fatty acids of lower molecular weight, and thus gives rise to an increase in acidity, iodine number and probably Hehner number; and to a decrease in saponification and Reichert-Meissl numbers. A third group splits the fats, then consumes the liberated fatty acids of both high and low molecular weight; the acidity of the fat necessarily increases. As a rule moulds produce hydrolysis, then consume the liberated volatile acids and thus cause higher values in the acidity, iodine number and probably Hehner number, and lower values in the saponification and Reichert-Meissl numbers. While the bacteria and most of the moulds attack only free glycerol, certain moulds attack the combined glycerol of fats and form odoriferous esters. Some yeasts produce hydrolysis of the glycerides, while other yeasts attack the combined glycerol with the formation of compounds of ethereal odor. There is positive proof that many fat-splitting organisms secrete enzymes by means of which hydrolysis is produced; possibly all lipolytic organisms act by virtue of lipases.

The enzyme lipase, sometimes called steapsin, is widely disseminated in Nature. It occurs in the seeds of many plants and in many animal tissues. Lipase is able not only to split esters and glycerides, but also to synthesize them from a mixture of acid and alcohol or glycerol. The enzyme which acts best at a moderately elevated temperature may produce complete hydrolysis of fats; this is especially true of the vegetable lipase. The relation of the enzyme catalase to the chemistry of the fats, if such a relation exist, is at present but little understood.

Of the atmospheric gases, nitrogen has no action upon fats and oils. Carbon dioxide causes a tallowy taste and an increase in acidity. Moisture hydrolyzes the glycerides, especially in the presence of a lipase, heat or light. Oxygen increases the specific gravity, melting point, refractive index, acidity and saponification number and at times the Reichert-Meissl number; and decreases the heat of combustion, iodine and Hehner numbers. Acids of lower carbon content, which belong to both the fatty and oxalic series, are formed, as are hydroxy acids and lactones;

aldehydes and active oxygen frequently occur in such fats. Many of these changes may be explained by the oxidation of the insoluble fatty acids; the glycerol is frequently oxidized. Oxidized fats possess a rancid smell and taste. Fine division of an oil, *e.g.*, its absorption by means of wool, greatly accelerates the oxidation. Ozone forms compounds with unsaturated acids and their glycerides, usually by addition at the double bonds.

Light, as well as heat, may produce both stereochemical and purely chemical changes in fats and oils. Both heat and light may give rise to polymerization. Light may change maleic forms to their geometric isomerides of the fumaric type. Heat may cause a shifting of double bonds. Both heat and light greatly accelerate the action of moisture and thus aid in increasing the acidity. Both accelerate the action of oxygen and thus play a part in decreasing the iodine number. Fats and oils, which have been exposed to the action of light, respond to certain color-forming reagents, long before changes may be detected organoleptically. Cold may somewhat retard, but does not stop the action of the natural forces upon glycerides.

Fats may be acid, or rancid, or acid and rancid. In acid fats the content in free fatty acids has become rather high by the hydrolysis of the glycerides. This hydrolysis has been produced by the action of organisms, by their enzymes, by tissue lipases, by the action of water in the presence of light, or by the action of heat. The rancidity of rancid fats is due to the presence of aldehydes or of odoriferous esters. Aldehydes are formed by oxidation of the fats and oils, especially of the small quantity of free fatty acid which occurs normally in fats. Esters are produced by the action of certain moulds and yeasts which can attack combined glycerol. In fats which are both rancid and acid more complex forces have been at work. The high acidity may be explained by the action of one or several of the acid-forming forces, while the rancidity is due to subsequent oxidation of the liberated acids or glycerol or of both. Then certain organisms, especially some of the moulds, have power not only to hydrolyze fats but also to attack combined glycerol with the production of esters; such organisms may thus give rise to both acidity and rancidity at the same time. Finally it is quite possible that acid-forming forces, oxidation, and ester-forming organisms may all act simultaneously with production of both rancidity and acidity. Acidity may easily be measured quantita-

tively by solution of the fat in a suitable solvent and titration of the free fatty acids. Rancidity is more difficult to measure, some investigators advise distillation of the rancid fat with steam and colorimetric determination of the aldehydes in the distillate, others have attempted to determine the content of volatile esters.

Although, from their chemical nature, fats and oils appear to be stable bodies, yet they are exceedingly susceptible to the forces of Nature, which call forth many changes in the chemical, physical and organoleptic properties of the glycerides. Organisms, their enzymes, tissue enzymes, the gases of the atmosphere, heat and light all play a part in producing these changes, which finally lead to those two related, but not identical, phenomena—acidity and rancidity.

[The author desires to acknowledge his indebtedness to Dr. M. E. Pennington and to Dr. E. Q. St. John, for assistance and valuable suggestions in the preparation of this paper.]

BIBLIOGRAPHY.

[1] Repertorium der analytischen Chemie vi, 1886, 489.
[2] Berichte der deutschen botanischen Gesellschaft vi, 1888, page ci.
[3] Naturwissenschaftliche Wochenschrift v, 1890, 343.
[4] Naturwissenschaftliche Wochenschrift v, 1890, 374.
[5] Annali dell' Instituto d' Igiene Sperimentale della R. Universita di Roma. Nuova Serie i, 1891, 109.
[6] Forschungsberichte über Lebensmittel i, 1894, 23.
[7] Forschungsberichte über Lebensmittel ii, 1895, 290.
[8] Zeitschrift für analytische Chemie xxxiv, 1895, 633.
[9] Forschungsberichte über Lebensmittel ii, 1895, 421.
[10] Annals of Botany xiii, 1899, 363.
[11] Zeitschrift für analytische Chemie xxxviii, 1899, 10.
[12] Zeitschrift für Untersuchung der Nahrungs- und Genussmittel iii, 1900, 432.
[13] Zeitschrift für Untersuchung der Nahrungs- und Genussmittel iii, 1900, 606.
[14] Centralblatt für Bakteriologie II Abteilung; vi, 1900, 131, 166, 209.
[15] Centralblatt für Bakteriologie II Abteilung; viii, 1902, 11, 42, 74, 107, 140, 171, 211, 248, 278, 309, 342, 367, 406.
[16] Archiv für Hygiene xiii, 1891, 1.
[17] Centralblatt für Bakteriologie II Abteilung, iii, 1897, 177.
[18] Centralblatt für Bakteriologie II Abteilung, iii, 1897, 497.
[19] Archiv für Hygiene xli, 1902, 119.
[20] Archiv für Hygiene xli, 1902, 328.
[21] Centralblatt für Bakteriologie II Abteilung, xv, 1905, 53.
[22] Centralblatt für Bakteriologie II Abteilung, xv, 1905, 422.
[23] Zeitschrift für analytische Chemie xviii, 1879, 431.
[24] Milchzeitung xviii, 1889, 461.
[25] Chemiker Zeitung xiv, 1890, 406.
[26] Forschungsberichte über Lebensmittel i, 1894, 22.
[27] Chemische Revue über die Fett- and Harz- Industrie v, 1898, 169.
[28] Bulletin du Departement de l'Agriculture aux Indes Néerlandais, No. ix (Microbiologie iii), 1907.
[29] Apotheker Zeitung xxii, 1907, 598.

[20] Centralblatt für Bakteriologie II Abteilung, xx, 1908, 474.
[21] Chemical Abstracts iii, 1909, 445. Jahresberichte über die Fortschritte der Tierchemie, xxxvii, 1907, 926.
[22] Monatshefte für Chemie xi, 1890, 272.
[23] Proceedings of the Royal Society of London, xlviii, 1890, 370.
[24] Journal of the American Chemical Society xxv, 1903, 949.
[25] Berichte der deutschen chemischen Gesellschaft xxxv, 1902, 3988.
[26] Chemisches Centralblatt iv Folge, i Jahrgang, Band i, 1889, 603. The same iv Folge, i Jahrgang, Band ii, 1889, 295.
[27] American Chemical Journal xxiv, 1900, 491.
[28] American Journal of Physiology vi, 1902, 331.
[29] American Chemical Journal xxvii, 1902, 481.
[40] Journal of the Society of Chemical Industry xxii, 1903, 69.
[41] American Chemical Journal xxxi, 1904, 521.
[42] Zeitschrift für physiologische Chemie xlii, 1904, 149.
[43] Journal of Biological Chemistry ii, 1906–7, 391.
[44] Journal of Biological Chemistry ii, 1906–7, 397.
[45] Journal of Biological Chemistry iv, 1908, 149.
[46] Biochemische Zeitschrift xii, 1908, 343.
[47] Helfenberger Annalen, ii Band des ii Dezenniums, 1897, 138.
[48] Monatshefte für Chemie xxv, 1904, 355.
[49] Philippine Journal of Science i, 1906, 117.
[50] Proceedings of the Royal Society of London lxxii, 1903, 31.
[51] Journal de Physiologie et de Pathologie Generale v, 1903, 503.
[52] Beiträge zur chemischen Physiologie und Pathologie vii, 1906, 1.
[53] Centralblatt für Bakteriologie, II Abteilung, xxi, 1908, 1.
[54] Centralblatt für Bakteriologie, II Abteilung, xxi, 1908, 609.
[55] University of California Publications. Pathology. On Fermentation. Berkeley. The University Press, page 175, 1907.
[56] University of California Publications. Pathology. On Fermentation. Berkeley. The University Press, 1907, page 189.
[57] The Soluble Ferments and Fermentation. Second Edition. Cambridge University Press. 1901, page 237.
[58] Zeitschrift für analytische Chemie xxxv, 1896, 471.
[59] Versuch einer populären Chemie, 1795, 331.
[60] Journal de Pharmacie et de Chimie (3) xxvii, 1855, 96.
[61] Analyst ix, 1884, 17.
[62] Annales de l'Institut Pasteur i, 1887, 347.
[63] Zeitschrift für angewandte Chemie, 1889, 62.
[64] Naturwissenschaftliche Wochenschrift v, 1890, 331, 354, 364.
[65] Journal of the Society of Chemical Industry x, 1891, 29.
[66] Zeitschrift für angewandte Chemie, 1892, 171.
[67] Chemiker Zeitung xvii, 1893, 434.
[68] Chemiker Zeitung xvii, 1893, 1453.
[69] Chemiker Zeitung xvii, 1893, 1848.
[70] Forschungsberichte über Lebensmittel i, 1894, 344.
[71] Zeitschrift für angewandte Chemie, 1890, 482
[72] Le Stazioni Sperimentali Agrarie Italiane xxx, 1897, 613.
[73] Forschungsberichte über Lebensmittel iv, 1897, 197.
[74] Analyst xxiii, 1898, 36.
[75] Chemical Technology and Analysis of Oils, Fats and Waxes. Third Edition, 1904, 834.
[76] Le Stazioni Sperimentali Agrarie Italiane xxxi, 1898, 485.
[77] Zeitschrift für Untersuchung der Nahrungs- und Genussmittel, i, 1898, 759.
[78] Journal of the American Chemical Society, xxi, 1899, 975.
[79] Zeitschrift für analytische Chemie xxix, 1890, 1.
[80] Journal of the Society of Chemical Industry, iii, 1884, 543.
[81] Zeitschrift für Untersuchung der Nahrungs- und Genussmittel, iv, 1901, 975
[82] Journal of the Society of Chemical Industry xviii, 1899, 556.
[83] Journal of the American Chemical Society xxiv, 1902, 348.
[84] Journal of the American Chemical Society xxv, 1903, 711.

[85] Chemical Technology and Analysis of Oils, Fats and Waxes. Third Edition, 1904, 21.
[86] Apotheker Zeitung xx, 1905, 690.
[87] Pharmaceutische Centralhalle für Deutschland xlv, 1904, 839.
[88] Berichte der deutschen chemischen Gesellschaft xxxix, 1906, 2735.
[89] Berichte der deutschen chemischen Gesellschaft xxxix, 1906, 2844.
[90] Chemiker Zeitung xxxi, 1907, 1199.
[91] American Journal of Pharmacy lxxix, 1907, 308.
[92] Journal of the American Chemical Society xxx, 1908, 874.
[93] Zeitschrift für physiologische Chemie xxv, 1898, 434.
[94] Chemisches Centralblatt iv Folge, viii Jahrgang, Band i, 1896, 520.
[95] Chemiker Zeitung xxii, 1898, 991.
[96] Zeitschrift für physikalische Chemie xxvi, 1898, 337.
[97] Annalen der Physik und Chemie, herausgegeben von Wiedemann. Neue Folge, xlviii, 1893, 389.
[98] Chemical Technology and Analysis of Oils, Fats and Waxes. Third Edition, 1904, 20.
[99] Verhandlungen der Naturforschenden Gesellschaft in Basel xv, 1903-4, 225.
[100] Zeitschrift für Untersuchung der Nahrungs- und Genussmittel ix, 1905, 90.
[101] Zeitschrift für Untersuchung der Nahrungs- und Genussmittel i, 1898, 377.
[102] Chemical Technology and Analysis of Oils, Fats and Waxes. Third Edition, 1904, 19.
[103] Chemiker Zeitung xxxi, 1907, 434.
[104] Zeitschrift für Untersuchung der Nahrungs- und Genussmittel xv, 1908, 65.
[105] Berichte der deutschen chemischen Gesellschaft xl, 1907, 878, 1153.
[106] Journal of the Society of Chemical Industry xvi, 1897, 391.
[107] Analyse der Fette- und Wachsarten, 4 Auflage, 1903, 23, 27.
[108] Yearbook of the United States Department of Agriculture, 1907, 197.
[109] United States Dept. of Agriculture, Bur. of Chemistry, Bulletin 115, 1908, 57.
[110] Michigan State Agricultural College Experiment Station, Technical Bulletin No. 1, 1908.
[111] Centralblatt für Bakteriologie II Abteilung, xxii, 1908, 22.
[112] Chemiker Zeitung xv, 1891, 410.
[113] Forschungsberichte über Lebensmittel ii, 1895, 283.
[114] Zeitschrift für analytische Chemie xxxvii, 1898, 301.
[115] Zeitschrift für Untersuchung der Nahrungs- und Genussmittel iii, 1900, 324.
[116] Die landwirtschaftlichen Versuchs-Stationen li, 1899, 1.
[117] Forschungsberichte über Lebensmittel ii, 1895, 113.
[118] Journal für praktische Chemie. Neue Folge, lv, 1897, 450.
[119] United States Department of Agriculture, Bureau of Chemistry, Bulletin 107 (revised), 1908, 142.
[120] United States Dept. of Agriculture, Bur. of Chemistry, Bulletin 109 1908, 7.
[121] Analyst ix, 1884, 170.
[122] Commercial Organic Analysis, 3rd Edition, Volume ii, Part 1, 1899, 104.
[123] Chemical Technology and Analysis of Oils, Fats and Waxes. Third Edition, 1904, 277.
[124] Journal of the Society of Chemical Industry iii, 1884, 540.
[125] Dingler's Polytechnisches Journal ccxvii, 1875, 314.
[126] Archiv für Anatomie und Physiologie. Archiv für Physiologie, 1878, 181.
[127] Journal of Physiology xii, 1891, 72.
[128] Dingler's Polytechnisches Journal ccxliv, 1882, 303.
[129] American Chemical Journal xxiii, 1900, 173.
[130] Jahrbuch der Chemie, herausgegeben von Richard Meyer, x Jahrgang, 1900, 382.
[131] Chemische Revue über die Fett- und Harz-Industrie iv, 1897, 192.
[132] Chemische Revue über die Fett- und Harz-Industrie v, 1898, 209.
[133] Zeitschrift für Untersuchung der Nahrungs- und Genussmittel i, 1898, 552.
[134] L'Orosi xxi, 1898, 253.

ERRATA.

Vol. CLXVIII, p. 381, line 14 from bottom—for totuol read toluol.
Vol. CLXVIII, p. 383, line 14 from top—for π read π_1.

FRANKLIN INSTITUTE

(Stated Meeting, held Wednesday, November 17, 1909.)

BAKELITE, A CONDENSATION PRODUCT OF PHENOLS AND FORMALDEHYDE, AND ITS USES.

BY

DR. LEO H. BAEKELAND.

[Bakelite is a liquid compound of phenol and formaldehyde which on solidification resembles amber in appearance and when used in combination with wood, paper, asbestos, graphite and other substances produces a solid non-resistant, non-inflammable insulating material which promises to have many applications in various industries.]

It has long been known that formaldehyde may react upon phenolic bodies in various complex ways resulting in products very unlike in chemical and physical properties. Some of these so-called condensation products are soluble in water; under some conditions they become crystalline, under others amorphous and resin-like.

The product to which the name "bakelite" has been applied is of the latter type. It is a most inert body being infusible and insoluble in all ordinary solvents and capable of withstanding the action of almost all chemicals. It resembles, somewhat, in some of its properties, amber, hard-rubber, and the celluloids.

The history, the chemical considerations, and the experimental investigations, that led to the production of a material of commercial value have been described at length in previous papers and, therefore, will not be considered at this time.* The mode of preparation, however, having an intimate relation to its possible applications, must be briefly reviewed.

The preparation of bakelite may be carried on in a single operation or in several stages, each stage furnishing a product having distinct properties. Ordinarily three stages of transfor-

* Jour. of Industrial and Engineering Chemistry, Mar., 1909; *Idem*, Aug., 1909; Transactions of the Am. Electrochemical Soc., May, 1909.

mation are employed in each of which the material acquires distinct properties. In these successive forms it may be designated respectively, bakelite *A*, bakelite *B*, and bakelite *C*. The preparation of these condensation products *A* and *B*, and their ultimate transformation into *C* for technical purposes, constitute the bakelite process.

Bakelite *A* is prepared by adding to about equal amounts of phenol and formaldehyde a small quantity of an alkaline condensing agent and gently heating. The mixture separates into two layers, the upper, a supernatant aqueous solution; the lower, a layer of heavy liquid which is bakelite *A*.

There may be thus obtained, at will, either a thin liquid called *thin A* or a more viscous mass, *viscous A* or a *pasty A* or even, if the reaction be carried far enough, a *solid A*.

The condensation agents best adapted to the reaction are alkaline salts, or salts, which in hydrolyzing split into weak acids and strong bases such as sodium acetate, the alkaline carbonates, borax, sodium sulphite, etc. These must be employed in relatively small quantities to secure the desired results. Acid condensing agents may also be employed but these result in the formation of soluble and fusible resins while the bases yield an insoluble and infusible product. Moreover, as there may remain in the final product traces of the condensing agent, the advantage of employing a base rather than an acid is obvious.

At ordinary temperature, *A* may be liquid or viscous or pasty or solid. It is soluble in alcohol, acetone, phenol, glycerine and similar solvents. It is also soluble in NaOH. Solid *A* is very brittle and melts if heated. All varieties of *A* heated long enough under suitable conditions, will change first to *B* and finally into *C*.

B is sold at all temperatures, brittle and somewhat harder than *A* at ordinary temperatures. It is insoluble in all solvents but may swell in acetone or phenol without entering into complete solution. If heated it does not melt but softens decidedly and becomes elastic and somewhat rubber-like and on cooling becomes again hard and brittle. Further heating under suitable conditions changes it into *C*. Although infusible, *B* can be molded under pressure in a hot mould to a homogenous coherent mass which can be further changed to *C* by the proper application of heat.

C is infusible in all solvents, unattacked by acetone, indifferent to ordinary acids or to alkaline solutions and yields only to the action of boiling concentrated sulphuric acid and to nitric acid. It does not seriously soften if heated and the temperature may with safety be raised to 300° C. At much higher temperature it chars without entering into fusion.

Bakelite *C* is an excellent insulator both of heat and electricity and has a specific gravity of about 1.25. It is very hard and cannot be scratched with the finger nail, in which respect it is far superior to shellac or even to hard rubber and celluloid but lacks the great elasticity and flexibility of hard rubber and celluloid, and this is its most serious drawback.

Bakelite *A* heated above 100° C. without any precaution produces a spongy mass of *C* due to the evolution of gases from the decomposition of the condensation product. This is entirely avoided by heating the product in a bakelizer, a closed vessel subjected to an air pressure of 50 or, better, 100 lbs. per square inch and a solid homogeneous mass of bakelite *C* of the exact shape of the recipient is assured.

Instead of pouring liquid *A* into a mould to form an object of the desired shape of solid bakelite, it may be applied as a coating to an object of different material, such as wood, which, after treatment in a bakelizer, acquires a hard brilliant coat of bakelite, superior to any varnish or the most expensive Japanese lacquer. Better still, by using a more liquid form of *A*, soft wood may be impregnated with it resulting, after bakelizing, in the equivalent of a very hard wood, proof against dry rot, dilute acids, water, and steam. Indeed, in this application to the transformation of cheap soft woods with a material having the properties of the most expensive hard wood, the process promises most fruitful results.

As a binder for all inert filling materials such as sawdust, woodpulp, asbestos, bakelite has a wide field of application. Among the more impressive applications of this class may be mentioned its use in the manufacture of grindstones and again in the manufacture of oilless bearings of which the aggregate is graphite. Mixed with fine sand or slate dust it can be applied in the form of a dough to the inside of metallic pipes, containers or pumps, which, after bakelizing, produces an acid-proof lining very useful in chemical engineering. Among other applications

may be named, steam and acid-proof valves and steam packings, phonograph records and the thousand and one other articles of domestic and industrial utility now made of hard rubber, celluloid or kindred substances.

In the electrical industry bakelite has already received the test of some actual use. There too its possible applications are numerous. Armatures and field coils of dynamos and motors instead of being treated with ordinary resinous varnishes can be impregnated with *A*, which treated in a bakelizer becomes a solid, infusible, insulating mass. This may ultimately permit an increase of the allowable overload in motors and dynamos by eliminating the possibility of the melting or softening of such insulating varnishes as are now used. This part of the subject has not, as yet, received more than preliminary investigation, and, for the present, may be dismissed for a consideration of what has already been achieved in the production of moulded insulators, which have been manufactured successfully for several months.

The element of time is a most important feature in moulding operations. To insure economy of manufacture, the moulds whose first cost is generally high, must remain in use not longer than a determinate time for each piece moulded. For that reason the methods that are employed require the use of the mould for the very minimum of time.

As stated above the use of bases permits the production of a variety of *A* that is solid though still fusible. This is as brittle as ordinary rosin and can be pulverized and mixed with suitable filling materials. A mixture of this kind is introduced in a mould and subjected to pressure at a temperature ranging from 160° to 200° C. The bakelite *A* melts, impregnating the filler and at the same time is rapidly transformed into bakelite *B*. The latter, as has been noted, is infusible and the object moulded can therefore be expelled from the mould without changing its form after a very short time and the mould can now be refilled. The moulded articles now in condition *B*, may at any convenient time be placed in the bakelizer without the use of any moulds and finally transformed into bakelite *C* of maximum strength, hardness, and resisting power.

For electric insulators which are subjected to high temperatures, mineral fillers such as finely ground asbestos, clay or mica should be used. If the temperature specifications are not im-

portant, organic fillers like woodpulp or ground sawdust are available and furnish suitable moulding compositions of which the insulating coefficient is frequently higher than that of asbestos.

Not enough experience has yet been gathered to determine the relative merits of porcelain and bakelite-asbestos or bakelite-mica insulators for high voltage insulation. But for insulation in third-rail systems where the vibration of passing trains is very destructive to the porcelain, bakelite-asbestos has indicated decided superiority after several months of continuous service as well as by direct laboratory tests. Besides greater strength it has shown more regularity in manufacture and allows more accurate moulding, permitting closer designs with a smaller margin of safety. It has the further merit that there is no difficulty whatever in imbedding metallic parts like bolts, cores, screws, washers or reinforcing members in the moulded mass.

The tables which follow are condensed from some comparative results communicated by users of bakelite who previously had acquired great skill in the manufacture of other excellent insulating compounds.

MECHANICAL STRENGTH TESTS.

No.	Name of piece.	Bakelite.	Remarks.
7	Square tube Thickness .103 inches...	Transverse strength, 6-inch centres, 1850 pounds	Asbestos hard-rubber composition 1700 pounds.
8	Rail insulator	Ultimate strength compression 96,000 to 110,000 pounds Ultimate strength tension, 3200 to 5500 pounds Impact test, no limit found for same blow as porcelain was submitted to	Porcelain 45,000 to 85,000 pounds. Porcelain 1400 to 2300 pounds. Porcelain 38 to 100 blows.
9	Cup piece, hollow cylinder 3 inches high, 1¼ inches diameter, .045 inch thick	Ultimate compressive strength 2550 pounds	Loaded on top.

HEAT TESTS.

No.	Name of piece.	Bakelite.	Remarks.
10	Valve interior	At 265 pounds, steam about 460° Fah. for one hour	No effect on the composition.
11	Packing nut graphite composition	Tight at 65 pounds, steam 200 r. p. m.	Could turn 3 inch shaft by hand.

ELECTRICAL TESTS.

No.	Name of piece.	Bakelite.	Remarks.
1	Spool	Punctured at 16,000 to 18,000 volts	Asbestos hard-rubber composition punctured at 4000 to 8000 volts.
2	Square tube Thickness .103 inch	Punctures at 21,000 volts	Asbestos hard-rubber composition punctured at 17,000 volts.
3	Washer Thickness .062 inch	Punctured at 20,000 volts	Asbestos hard-rubber composition punctured at 11,000 volts.
4	Discs of various compositions		
	Thickness .0625 inch	Punctured at 45,000 volts	These tests are still unfinished and were made on various bakelite compositions.
	Thickness .162 inch	Punctured at 31,000 volts	
	Thickness .165 inch	Punctured at 22,000 volts	
	Thickness .375 inch	Punctured at 42,000 volts	None on pure bakelite.
5	Disc Thickness .095 inch	Punctured at 18,000 volts	Asbestos hard-rubber composition punctured at 1500 volts.
6	Cup insulator Thickness .375 inch	Punctured at 42,500 volts.	
7	Line insulator	Arc to pin, dry at 50,000 volts	Used on 11,500 volt line.
8	Rail insulator	Resistance dry, 5625 megohms	Porcelain resistance dry, 4550 megohms.
		Resistance wet, 0.5 to 65 megohms (These tests are only approximate in megohms)	Porcelain resistance wet, 0.2 to 10 megohms.
		Arc over hook bolt to rail 27,000 volts	Porcelain arc over 26,400 volts.

NOTE.—All of the bakelite insulation shows an unusual uniform resistance at varying temperatures from 0° to 300° Centigrade and does not soften at much higher temperatures. Most of the insulation contained about ⅓ bakelite and ⅔ finely divided asbestos.

SMOKE PREVENTION.

REPORT BY THE UNITED STATES GEOLOGICAL SURVEY.

Among the recent discussions of the smoke nuisance and waste, and their remedies, is a report of the United States Geological Survey numbered Bulletin 373, by D. T. Randall and H. W. Weeks, entitled "The Smokeless Combustion of Coal in Boiler Plants."

The burning of coal without smoke is a problem that concerns the Government directly because of the advantages of smokeless combustion in boiler plants installed in public buildings and on naval vessels, and the Survey's technical experts have therefore made careful and thorough tests to determine the conditions necessary to prevent smoke.

Studies were made in thirteen of the larger cities of the country, more than 400 plants have been examined. The report gives in detail the results of the observations made at these plants, together with the results of smoke tests and observations made at the Survey's fuel-testing plants at Norfolk and St. Louis.

The conclusions reached show that in properly constructed plants smoke prevention is possible and is economically desirable, though in ordinary boiler furnaces only coals containing large percentages of fixed carbon can be burned without smoke except by expert firemen. Of the existing plants some can be remodeled with advantage; others must continue to burn coals that are high in fixed carbon or to burn other coals with inefficient results and more or less smoke. To replace these inefficient plants with new, well-designed equipments is the only remedy for the loss and the nuisance they occasion.

THE TESTING OF EXPLOSIVES WITH REGARD TO THEIR ADMISSION FOR TRANSPORTATION.

BY

GEH. REG. RAT PROF. DR. W. WILL.

[Translated from the *Zeit. für das gesamte Schiess- und Sprengstoffwesen* for August 15, 1909. By W. J. Williams, F.I.C.].

For some time past there has been in progress a revision of the regulations governing the testing of explosives and powder in relation to their acceptance for transportation, to be incorporated in the new German Railroad Traffic Regulations. The Commission appointed to conduct the investigation and formulate a code of rules has arrived at a provisional conclusion and the results which are presented in the accompanying specifications have been embodied in section *CIa* of the Railroad Traffic Regulations.

In pursuing this investigation the endeavor was made to follow the plan indicated in the writer's communication on the subject to the Sixth International Congress in Rome and to make the conditions under which explosives may be safely transported dependent upon a series of investigations. Broadly considered, these consist of definite methods of determining the properties which appear of importance as endangering traffic.

Besides the chemical composition there should be determined the stability in storage, the behavior on ignition, the sensitiveness to mechanical influences the possibility of intermixture and other hazardous features. Further, there is to be taken into consideration to what extent the reciprocal influences of materials packed together or shipped together would be productive of danger.

According to the Railroad Traffic Regulations, explosives consist of those explosively dangerous substances which can only be provisionally accepted for forwarding. All substances capable of explosion are included, with the limitation that certain explosive substances, such as those which are not used for shooting and blasting, those which do not explode on ignition and those which are not more sensitive to shocks and blows than di-

nitro-benzol are not considered explosives within the meaning of the regulations.

It appeared desirable to classify explosives under three fundamental groups, namely: (I) *high explosives,* (II) *powders* and (III) *other substances capable of explosion,* and the two first again into sub-groups.

Group I.—The *high explosives* include:

1. Ammonium nitrate explosives.
2. Organic nitro-compounds.
3. Nitrated chlorhydrin.
4. Nitro-cellulose.
5. Chlorate and perchlorate explosives.
6. Black powder and similar explosives.
7. Dynamite and similar explosives.

Group II.—The *powders* include:

1. Smokeless colloided nitro-cellulose powder without nitroglycerin.
2. Smokeless colloided nitro-cellulose powder containing nitroglycerin.
3. Black powder.

According to the result of the investigation it was shown which explosives could be accepted in packages for transportation as explosives *safe in handling* in unlimited quantities. Classified under their respective groups these are:

Under Group I.—The so-called ammonium nitrate explosives, the not dangerous nitro-compounds, damp nitro-cellulose and certain explosives similar to black powder.

Under Group II.—Explosives which can only be carried in packages in quantities not exceeding 200 kilograms (440 lbs.) which include: the more insensitive chlorate and per-chlorate explosives; wet organic nitro-compounds which are more dangerous than picric acid; nitrated chlorhydrin.

Under Group III.—Explosives which can only be carried in special car loads, such as dynamite; the more dangerous black powders; gun-cotton and collodion-cotton; chlorate and perchlorate explosives.

Powders may be forwarded in packages in unlimited quantities, either as in Group I, including smokeless nitro-cellulose powders (also those containing nitroglycerin) which are well colloided and have certain definite conditions of stability, or as in Group II only in car-loads, which include those nitro-cellulose powders which do not attain these conditions of stability, black

powder for shooting purposes (as a propellant) and similar powders.

If certain regulations as to packing are followed, these shooting powders of Group II can be forwarded in packages in quantities up to 200 kilograms (440 lbs.).

The admission of an explosive to railroad transportation, under any one of these groups, is governed by the results of the above mentioned tests, wherein it has shown itself to be as safe as those well known and comparable explosives tested simultaneously.

The methods of testing will be described later by my colleague, but it may be said in advance that such explosives as may be admitted to transportation in packages must have their respective composition and properties described as accurately as possible. For transportation in car-loads and with more stringent precautionary measures wider limits may be permitted in this respect.

This list at once becomes very large. This must, however, be tolerated until our experience in the mode of procedure is considerably increased. It may later be possible to simplify matters by including the single types in definite groups determined by numerous experimental researches.

It can be foreseen that an enlargement or the abolition of groups may be necessary, but such a preliminary attempt in the classification of explosives for transport based on systematic experimental tests may develop many errors, especially, as a comparatively short time was available for conducting the investigation. Despite this, the new ordinance appears an advance in safeguarding traffic and to be beneficial to the explosive industry in contrast to the regulations in force before their adoption.

The explosive manufacturer can now adapt his method of production to the prescribed requirements in keeping with the strictly defined tests and with the traffic regulations.

Further, it may be hoped that the prescribed tests will serve to prevent the appearance in commerce of such explosives as are prepared without adequate technical knowledge which are, on that account, dangerous in handling and in transit, and that the results based on extensive experimental work will prove of value in framing international traffic regulations.

THE TESTING OF EXPLOSIVES WITH REGARD TO THEIR ADMISSION FOR TRANSPORTATION.

BY

PROF. DR. F. LENZE.

CHARLOTTENBURG.

[Translated from the *Zeit. für das gesamte Schiess- und Sprengstoffwesen*, for August 15, 1909. By W. J. Williams, F. I. C.]

In a previous article the investigations for the testing of explosives with a view to their admission to railroad transportation, recently promulgated in Germany, were briefly reviewed. They consisted, chiefly, in the determination of those properties which affect their safety in transportation and are, therefore, of importance in relation to jeopardizing traffic. These are: (*a*) *Stability in Storage,* (*b*) *Sensitiveness to Mechanical Influences* (*Blows and Friction*), (*c*) *Inflammability and Liability to Explosion in Fire or from the Influence of High Temperature generally.*

The most important of these properties appears to be *the liability to explosion in fire or from high temperatures,* since the manufacturer, in his own interest, may be relied upon to supply an explosive that shall be sufficiently stable, while the risk from sensitiveness to blows and friction is rendered of less importance by the enforcement of the rules for safe packing provided for in the case of explosives by special rules in the Railroad Traffic Regulations. Unquestionably, suitable packing insures proper protection to the explosive from the influence of shocks and blows. Repeated experiments carried out on a large scale (violent falls of original boxes of dynamite and chlorate explosives from a heigh of 10 meters (32.8 feet) on paved floors, or the dropping of a 50 kilogramme (110 lb.) weight from this height on similar boxes) have proven this.

On account of the great importance with which these properties of explosives are regarded in relation to their conveyance, a method of testing has been specified for such *high explosives,* with the exception of nitro-chlorhydrin and nitro-celluloses containing water and alcohol. Moreover, their composition must be determined quantitatively, their reaction with litmus, their

tendency to form salts and other properties, (*e.g.*, capability of intermixture) which may require investigation on account of the special nature of the explosive. Thus the composite ammonium nitrate explosives are tested for safety of intermixture by the shaking (agitator) test; the ammonium nitrate explosives containing nitro-glycerin are especially tested for the exudation of nitro-glycerin on the addition of water; the simple nitro-compounds are tested for their tendency to form salts (*e.g.*, the formation of picrates); the nitro-celluloses for their content of water and alcohol, for admixtures (such as barium nitrate) and for their stability by a special explosion test at 145° C.; the chlorate explosives for their safety of intermixture (as with ammonium nitrate explosives) and for their behavior in alternate damp and dry storage; the dynamites are examined for the exudation of nitro-glycerin by sweating in heat (30° C.).

An explosive which has been in practical use for many years and whose properties are accurately known serves as a standard for all tests. These consist, then, of the determination of comparative and not of absolute values.

For powders, in addition to the testing of the finished product, there is specified an investigation of the ingredients, such as nitro-cellulose and nitro-glycerin, for their chemical stability by special methods, and for their purity. The test for finished powder consists in the determination of its chemical stability and its tendency to explosion in comparison with a powder of known composition. The test for tendency to explosion is of particular significance in judging of the danger from the powder during transit. This applies, also, to the explosives mentioned above.

A special test of the powder for its stability under prolonged storage is not essential as that feature is covered by the stability tests of the ingredients (nitro-cellulose and nitro-glycerin) and that of the finished powder at 132° and at 120° C., according to circumstances, and the determination of the explosion point of both components.

The most diverse products of chemical industry liable to explosion which enter into the question of conveyance by railroads as well as explosives and powders, are tested in a similar way to the nitro-compounds of the aromatic series for sensitiveness to mechanical influences and tendency to explosion. For these, picric acid is taken as the standard for comparison.

Most of these methods have already been proved reliable by the investigations of the Imperial Governmental Railroad Bureau covering a period of years. To some extent they were proposed even earlier for this purpose by the Royal Military Experimental Bureau.

It is not possible here to describe in complete detail the above-mentioned tests which have been prescribed for explosives admissible to conveyance on railroads. It is, however, established that the methods specified for testing explosives according to section *CIa* of the Railroad Traffic Regulations have proved more or less satisfactory. Only those methods will here be briefly considered which are of particular significance in the determination of the danger from explosives during transportation, such as: (*a*) The determination of stability during storage at 75° C. (*b*) The determination of sensitiveness to blows by means of the drop-hammer apparatus. (*c*) The test of liability to explosion.

a. The testing of explosives for storage stability consists of long continued storage of 10 grammes in loosely closed bottles at about 75° C. in thermostats or, better, in an oven heated by carbon tetrachloride (boiling point 76°–77° C.). It is prescribed that the explosive shall be stored 48 hours without showing visible change, which may be recognized generally by the appearance of yellow fumes (nitrogen oxides), by a peculiar odor or color, by large loss of weight, and so on. Actually, all the hitherto admitted explosives withstand this test for more than eight days, including ammonium nitrate explosives, nitro-compounds, chlorate explosives, black powder and explosives similar to black powder, and, also, many explosives containing dynamite while those of the first five groups may withstand the test several weeks. The method of storage at 75° C. at which, moreover, the simultaneous test of a standard explosive is specified, is, in the writer's estimation, especially adapted for the determination of stability, since the test carried out at a comparatively low temperature, and extending over a long period of time more nearly simulates practical circumstances than the so-called heat tests which are carried out at a considerably higher temperature (over 100° C.) and are used for testing nitro-cellulose and nitro-cellulose powder for stability. Such high temperatures are in many cases too great a strain for explosives when the presence of

nitro-glycerin and of other bodies of low stability is considered.

The so-called tests (*e.g.*, Abel's test) in which the beginning of the decomposition is shown by the coloring of a test paper or in a similar way, do not appear suitable for the above-mentioned purpose taking into consideration the extraordinary diversity in the composition of explosives and considering that certain explosives are compounded of very many ingredients and that the phenomena of decomposition of one of these ingredients may easily mask those of another. Furthermore, such tests cannot be applied with advantage for the reason that technical products (*e.g.*, di- or tri-nitrotoluol) may be used in the composition of explosives. These products are not prepared by the manufacturers with the highest degree of purity and are not intended to be so used. Another reason is that sometimes substances are incorporated in explosives which readily yield oxygen or are easily volatilized and would thus affect the reaction. These and many other causes make the test show a change which has no relation to the actual decomposition of the explosive. Such a method in the opinion of the writer is generally too sensitive.

Undoubtedly the test at 75° C. takes a somewhat long time, but for that reason it is, in most cases, more reliable than those above mentioned. If the process were perfected so as to be exactly suitable to the occasion, it might fitly be termed the "*normal test for the determination of the stability of explosives.*"

b. Concerning the usual method for testing the *sensitiveness to percussion* by means of the drop-hammer apparatus, adopted in the Railroad Traffic Regulations as one of their specified tests for explosives, reference may be made to the writer's report to the Sixth International Congress at Rome in 1906 upon tests for sensitiveness and the drop-hammer method. It may, however, be observed that the piston apparatus described in my earlier report and constructed by Dr. Kast has given good results in extended experiments by the Military Experimental Bureau. The communications of Dr. Kast (*Zeit. für das. ges. Sch.- und Spr.*, page 263) on the subject may also be compared.

c. As has been previously remarked, the testing of explosives for *liability to explosion* is of the greatest importance in judging of the hazard from such explosives in transport. The object in view is to obtain data upon their tendency to detonate

in case they should catch fire during transportation in large quantities on the railroad and also to determine whether a *mass detonation* is to be feared in such a fire. No exact method is, as yet, available for determining this property and reliance must, therefore, be placed upon empirical methods.

To arrive at the safest conclusion as to the liability to explosion, different methods have been chosen which collectvely enable the behavior of the explosion on ignition to be determined, the conditions being made as diverse as possible. The detailed methods are as follows:

1. As a test for *inflammability*—the action of the flash of a Bickford fuse on 3 grams of the sample.

2. To determine the *phenomena of decomposition by slow heating*—heating small samples from 0.1 to 0.5 grams to explosion or complete decomposition.

3. To determine the *phenomena of combustion and eventual explosion by instantaneous overheating*—by throwing 5 grams on a red hot iron plate.

4. To determine *the effect of a fierce fire on a confined explosive*—by calcining in a wood fire from 500 to 1000 grams, according to the density of the explosive, in sheet iron cases. At the same time comparative experiments are made in each of these trials with explosives whose behavior is accurately known from investigations frequently made in the past.

From the data obtained by these specal methods for determining the liability to explosion it may be seen without going farther, that in their selection allowance must be made for the possibilities which may arise from such an ignition. Experience has shown that all the methods taken together lead to a safe conclusion as to the greater or lesser liability to explosion, and moreover, to the proneness of the explosive to explode in a fire.

The liability to explosion of powders is tested by the determination of the behavior of a charge of 0.54 grams in a Trauzl lead block when ignited by a fulminating cap. A nitro-glycerin powder of known composition and of medium force serves for comparison. This method has been used for many years by the Royal Military Experimental Bureau as the basis of searching investigations on the various smokeless military and sporting powders and especially for the determination of their power,

which is characteristic of the tendency of the powder to explode in the packed condition in weak confinement.

This briefly outlines the more important methods now used in Germany for testing explosives which may be admitted to transportation on railroads. It should also be pointed out that the investigations undertaken by these methods must be supplemented by experiments *on the large scale* in those cases where there is a doubt as to which traffic-group the explosives should be assigned.

In conclusion I may remark that the regulations for testing explosives for admission to railroad transportation were drawn up after a large proportion of existent explosive materials had been tested in the most exhaustive way experimentally in two places, by already known, and by the newly devised, methods. These experimental investigations formed the basis upon which the testing regulations were founded, and were undertaken on the one hand by Privy Councillor Will at the Central Station for Scientific and Technical Investigation, at Neubabelsburg and on the other hand by myself, with the collaboration of Dr. Kast, in the Royal Military Experimental Bureau.

SPIRIT LEVELING IN WEST VIRGINIA.

A REFERENCE BOOK FOR ENGINEERS.

The United States Geological Survey has published, as Bulletin 399, a compilation, by S. S. Gannett and D. H. Baldwin, of the results of the spirit leveling done by the Survey in West Virginia during the years 1896 to 1908, inclusive. The work for the eight years since 1900 was done in co-operation with the West Virginia Geological Survey. This volume gives descriptions and elevations above mean sea level of bench marks in 48 counties, furnishing vertical control for nearly half of the State. The number of points whose elevation is thus given is nearly 1200. This bulletin will be found convenient for reference by every engineer or surveyor who has work to do in the State and by others who desire to know the exact elevation of any particular point.

DR. CHARLES B. DUDLEY.

1842–1909.

THE death of Dr. Dudley marks the completion of the life-work of an engineer whose services to the profession have been of the greatest value, both commercially and with respect to its scientific progress. The profession owes him a large debt for the thirty-four years during which he was chemist for the Pennsylvania Railroad, in which capacity he not only rendered invaluable service to that corporation but also to the profession at large by the publication of the results of many investigations. The title "Chief Chemist," by which he was officially known, but inadequately defines the diversified character of his routine duties and the many special investigations which he undertook. These necessitated a thorough scientific training coupled with an intimate acquaintance with the practical problems peculiar to the operation of a large railroad system. His versatility and appreciation of the many sides of questions connected with railway practice are attested by the number and value of the papers he contributed to the technical press and presented to the various technical societies with which he was identified. He was born at Oxford, Chenaugo County, New York, July 14, 1842, of New England parentage. His early education was obtained at the country schools and village academy. In 1863 he enlisted as a private soldier in the 114th New York Volunteers and remained in the service until the close of the war. He participated in several engagements and was severely wounded at the battle of Opequan Creek, near Winchester in the Shenandoah Valley, on September 19, 1864.

By his unaided effort he secured the means for a college education and entered the Academic Department of Yale College in 1867 from which he was graduated in 1871. In the fall of 1872 he entered the Sheffield Scientific School which conferred upon him the degree of Ph.D. in 1874. The following year he was appointed assistant in the Department of Physics at the University of Pennsylvania under Professor George F. Baker.

The same year he accepted the appointment of chemist for the Pennsylvania Railroad Company.

He was one of the founders of the American Association for Testing Materials and for many years its president. At the recent meeting of the International Association for Testing Materials held at Copenhagen, Dr. Dudley received the honor of election to the presidency of that body and it will be a matter of deep regret to his many warm friends that he has not been spared to preside over their deliberations at the convention to be held in this country in 1912.

He was a member of many English, French and German societies among which may be mentioned the Iron and Steel Institute of Great Britain and the Verein Deutscher Eisenhüttenleute. In this country he was identified with the American Society of Civil, Mechanical, Electrical and Mining Engineers. The Franklin Institute, of which he was a most valued member, is indebted for a number of valuable papers read at its meetings and published in the JOURNAL. These include such important topics as the "Composition and Properties of Steel Rails," "Wearing Power and Hardness of Steel Rails," "Bearing Metal Alloys," "Fuel Oils" and the "Ventilation of Passenger Cars on Railroads." In some of these were embodied investigations of an unusually searching character leading to deductions which aroused widespread discussion.

It is not alone as a technologist in the foremost rank of applied science that he will be recalled among his numerous friends, his admirable qualities of character will leave an even deeper impression in the minds of all who knew him than will his many professional attainments and achievements.

PERILS OF PEACE OR A SAFER AMERICA.

BY

W. H. TOLMAN, Ph.D.,

Director of the Museum of Safety and Sanitation, New York.

RÉSUMÉ OF THE POPULAR SCIENCE LECTURE DELIVERED AT WITHERSPOON HALL, FRIDAY EVENING, DECEMBER 10, 1909.

The lecturer was introduced by President Clark and spoke, in substance, as follows:

Millions Lost Annually.—The most conservative estimate of the loss, in cash, to the wealth of the United States through preventable accidents in the various industries is $125,000,000 a year.

There is (in New York) a Museum of Safety and Sanitation doing pioneer work in demonstrating that this year $125,000,000 can be saved at a moderate cost of insurance expenditure for prevention.

All Europe is doing that very thing now. The question for the United States, at last forced upon every employer, is suddenly looming up to such proportions that it casts its shadow over every field of labor, from the turning of a grindstone to the moving of every freight train, and that question is: Is it worth while?

Is it worth while for employers of American labor to adopt the safeguards which shall preserve to the nation the lives and limbs of the 500,000 workers now annually incapacitated or killed, whose wage-earning capacity, estimated at the low average of $500 apiece, means a loss to the country of 250 millions each year?

Engineers consider that half of this number of accidents is an unnecessary slaughter.

This is the sum lost through the failure to conserve the health and strength of the American wage-earners.

A New Safety Idea.—The New York Museum of Safety and Sanitation is organized for the protection of American life and labor from accidents and the lengthening of human life by lessening the perils of occupational diseases. This will be done through a permanent exposition of safety devices for the dangerous parts of machinery, perilous processes, by means of actual machines in operation, models, photographs, and other graphics. The executive headquarters of the museum are in the United Engineering Societies Building, 29 West 39th street, New York City. Philip T. Dodge is acting president. Among other influential charter members are Albert H. Gary, Cleveland H. Dodge, Albert R. Shattuck, Charles Kirchhoff, T. C. Martin, Robert A. Franks, Dr. L. L. Seaman, Prof. F. R. Hutton, Dr. Thomas Darlington and Richard Watson Gilder.

An Industrial Massacre.—An industrial massacre of thousands upon thousands of wage-earners took place last year and raised no outcry, perhaps because the killings and the maimings were spread over twelve months through the entire country.

Does it pay? All Europe is now agreed that it doesn't pay, and the various countries are maintaining museums of safety to prove it. The United States is not yet really maintaining one.

No workman should be forced by circumstances into accepting charity. The American workman's only capital is his daily work, which he hazards against disease and accident. When he gets old and can't work, there is nothing left for him but the poorhouse or the grave, nobody wants him.

Done in Germany.—What is done for the workman overtaken by an accident in Germany? In the first place he has the benefit of compensation at once, automatically, so to speak, as a right, and is not compelled to go to law, which so often means delay and a lessened compensation at the end. He has none of the apprehension and nervous dread assailing the American workman, in case of accident, for he knows that he and his family will receive the protection of a system, whose object is to bring him to the speediest recovery and restoration to his former wage-earning capacity.

The Wear and Tear of Labor.—The wage-earning capacity of the majority of laborers is not enough to enable them to lay aside sufficient for the emergency of accident, disease or old age; more particularly is this true when the rearing of a large family is in question, and during unproductive periods. In recognition of these conditions, Germany feels that she is obligated to work out a system by which the laborer, when incapacitated, does not become a charge on charity. She also realizes that the wear and tear of the laborer, as well as that of the machinery, should be a part of the cost of production, and as such be a direct charge against it accordingly.

The German employers are banded together according to trades, their accident premiums based on the risk and wages paid to their workman.

Safety Good Business.—The German industrialist knows that an accident will be most searchingly investigated, and if blame attaches to him, he will be heavily fined for the disbursement which his associates in the same trade must make in compensation. Then it does not take him very long to reach the decision that it is good business for him to equip his plant at once with the best safety devices. At this point the government co-operates by providing Museums of Safety, where every known device is assembled for the benefit of the employer and the benefit of the employee.

Looking to the Future.—The statement of S. H. Wolfe, at the 22d convention of the Inter. Assoc. of Accident Underwriters, 1909, is of the profoundest significance:

"I am of the opinion," said Mr. Wolfe, "that the system of governmental insurance is in its infancy and upon the present base will be reared a huge structure. When that time comes protection by private corporations will be critically weighed, and if its defects are such as to indicate the advisability of having this important political and economic function placed in the hands of the Government, it will be done.

"The United States is the only civilized country which does not grant compensation *automatically* to the injured workman."

Obsolete Rules, Dangers to the Government.—An influential attorney, dealing with thousands of negligence and liability suits annually, tells me that in these negligence suits, on the one hand technical and obsolete rules are invoked for the defeat of demands for reasonable compensation for the afflicted, and on the other arbitrary and ill-considered liability laws drive away the sense of justice from the hearts of employers.

In 1908 over twenty-five million dollars was contributed for protection against suits for damages in negligence cases. It was a fund for defense for the defeat of claims in negligence and not with a primary idea of securing compensation for the sufferer. The present system, taken as a whole, presents no aspect that does not indicate dangers to the government, hopeless futility as far as the injured are concerned, and to the employer nothing but the most commercially wasteful system that could be devised.

The Cost to the Taxpayer.—Consider for a moment the cost to the taxpayer of our judicial system. The salaries of judges, and the wages of the court attendants, exclusive of the administrative expenses and supplies, cost the taxpayers of New York City four million dollars in 1907.

In the county of New York 40,000 business men were drawn for jury duty: the number who served in 1907 were more than 29,000; an additional cost of $415,000 in jury fees. Another large sum must be added for general administration expenses, while it is impossible to estimate the inconvenience

and pecuniary loss to the business men who serve. Six millions annually is the expense to the New York City taxpayers alone in maintaining their judicial system, of which 60 per cent. is chargeable to negligence or accident cases; but not one cent of this large sum is of any direct aid or compensation to the victim of the accident.

The average payment to the injured victim is $500, of which the attorney usually gets one-half.

The Machine vs. the Man.—Thus far our industrialists have striven for higher speed and increased efficiency in the machine or tool. The whole wealth of inventive genius has been lavished on the machine, the thing, with little thought for the protection of the worker, the man, running it. No country can be in the front rank of civilization until as much care is taken of the workman as in the perfection of the machine.

This social philosophy found expression in the establishment of ten Museums of Safety during the last decade in Berlin, Paris, Vienna, Budapest, Milan, Munich, Stockholm, Zurich, Amsterdam and Moscow. We are the last to take up this question, but there is always hope for America, in that when she does wake up she generally surpasses all that has gone before.

Every Life Saved a National Asset.—The Berlin Museum of Safety, due to the efforts of a few public-spirited citizens, who first held an exposition of safety devices to arouse public interest and gain government support, after several years of effort was finally successful in 1903, when the government assumed the whole obligation for the purchase of a site, the erection of a building and an annual appropriation for its maintenance. Four years later it was necessary to enlarge it at an expense of 85,000 marks, so that to-day it is the finest example of the kind in the world. The government was so impressed with the excellence of the work accomplished by this museum that it has established another in Munich, the latter going a step further by the addition of a laboratory for perfecting devices.

"How is it," I asked the Director, "that you so easily secure the money from the government?" to which he replied, "I can get all the money I want, for the government feels that every dollar spent in this way is well spent, in that every life saved is a national asset."

The American Start.—In the United States it was not till 1907 that the first real progress was made through a two weeks' Exposition of Safety and Sanitation held in New York City. As a result of this small beginning, a Committee of Direction of 22 of the most representative scientific and technical editors was formed to guide the policy of the new movement.

The Committee decided, in view of the interest awakened by the first little exposition, to hold a second of longer duration, for two months, beginning April, 1908.

Among those exhibiting were the Westinghouse Air Brake, Penn. Ry., U. S. Steel Corporation, the Travellers' Ins. Co., Brown & Sharp, Yale & Towne, Carnegie Steel, altogether 122 exhibitors.

Insurance 7 Cents per Annum.—Our exposition displayed the latest devices for fighting fire. Prof. Irving Fisher, one of the directors of our Museum, informs me that in New England 70 years ago the rate on cotton and woolen mills averaged $3 or $4 per 100. To-day these mills are being insured against fire at a cost of 7 cents per annum. This enormous decrease has been accomplished by slight expenditures. In some factories the cost of improvements has been more than paid for in the savings on fire premiums in one year.

It is my opinion, that if similar care should be exercised in the application of safety devices, industrialists will be repaid a thousand fold in saving on payment of premiums and suit for damages.

Dust Removal.—The second great division of the Museum is sanitation, whatever affects the health of the worker.

In the Underwood factory at Hartford I found a complete system of exhausts and forced drafts, making the factory cool and comfortable.

"One day in August," said the vice-president, "I took the train from New York to Hartford. It was the hottest ride I think I ever took. Surely, I said to myself, the factory will be closed this afternoon. I found every one in his place, the rooms comfortable, due to the ventilation system. In fact, on my tour of inspection I walked some three miles, I should judge, without the slightest discomfort."

The Seaman Prize Essay.—As a member of the Board of Trustees of the New York Museum of Safety and Sanitation and from his interest in the problems of preventive sanitation, Dr. Lois L. Seaman, while at the XVI International Medical Congress in Budapest last month, offered a prize of 2,500 kroner, open to the world in any language on the following subject: "What should be the status of the medical department of an army, in order that its sanitary and hygienic conditions may be maintained at their highest efficiency, so that in the emergency of battle, its units may best respond to the call of its commanders." The award will be made by the Executive Committee of the XVII International Medical Congress. Dr. Seaman believes that many of the deaths from disease during an active campaign, as well as invalidism in the army due to disease, are easily preventable, failure to act accordingly constituting a crime against patriotism and humanity.

Bad Water and the Cost Sheet.—In a recent study which I made of the important industries in the United States I found only between 10 and 15 per cent. provided filtered water. It is well known that there is a direct connection between typhoid and impure water. Based on the estimate of a recent commission of the highest authority, 85 per cent. of the cases of typhoid in the United States are preventable. Lawrence, Mass., by the introduction of a public water filter, reduced the typhoid mortality 80 per cent. It is now demonstrated that for each life saved from typhoid two or three lives are saved from other diseases. Prof. Fisher states that at least 8 years could be added to human life by securing reasonably pure air, water and milk.

Mutuality.—A conscious effort to protect the employee by law, making his labor safe through the best safety devices; to maintain his health by improved methods of sanitation, tends to promote mutuality between employer and his employees. The discussion thus far has concerned safety and sanitation for labor in its various occupations. The Museum's third department, Mutuality, is a record of what the industrial world is doing to promote better relations between Capital and Labor.

Legislation in New York.—Assemblyman Cyrus W. Phillips, Chairman of the Committee on Causes of Industrial Accidents, appointed by the Legislature of New York, 1909, states: "The New York Museum of Safety and Sanitation can be made of great benefit to the State in its efforts to prevent industrial accidents, and I am of the opinion that the State is justified in supporting it. I shall advocate an appropriation for that purpose by the next Legislature. To be of the most value the exposition ought to be made permanent, with branches in different parts of the State. It must be within the reach of workingmen as well as employers. The men for whose benefit the safety devices are used must attend the exposition and become familiar with the devices and the various methods of protecting themselves and their fellow workmen that will be taught there. Rochester would be the natural location for a Western New York branch of the Museum. Such a Museum would be visited daily by manufacturers and artisans from all parts of the contiguous territory."

Progress in Holland.—The Hon. W. F. van Leeuwen, Burgomaster of Amsterdam, informs the New York Museum of Safety and Sanitation that, early in the Autumn, a bill will be introduced in the Dutch Parliament for the appropriation of a considerable sum of money for the erection of a Museum of Safety and Sanitation. The city of Amsterdam will provide the site. As Holland was among the very first countries in the world to open

a Museum of Safety and Sanitation, it is very fitting that she should worthily install this life-saving station.

In conclusion to show the practical and substantial benefit of the work of the Museum to the industrialist, to the worker and to the public.

At the annual dinner of the United States Steel Corporation in 1907 the chairman of the Museum was among the guests; being called upon for a speech, he made a general plea for the more adequate provision of safety appliances, particularly in the steel industry.

Another year passed, and another dinner came. "Mr. Kirchhoff," said Judge Gary, chairman of the Executive Committee, "last year offered some suggestions for safety devices in our steel industry. We acted on this and asked for suggestions from our own trained employees. Altogether, we have received 2,600, and have adopted the greater part of them." Not a bad idea to thus obviate a part of the interruptions of work and the improvement of service in such a vast enterprise.

The Committee of Safety.—In 1907, at a conference of the managers of the casualty departments of the U. S. Steel Corporation, a new and independent Committee of Safety was organized, whose object was the inspection of all the plants with reference to the prevention of accidents. It was to serve also as a clearing house for obtaining and disseminating the best information for safeguarding life and limb.

Standardizing Safety.—The Safety Committee is now standardizing appliances for machinery common to all the plants. Previously each had worked out its own method of guarding flywheels, gears, electric switchboards and other points of danger. They are now seeking to determine, from among the different methods in use, which are the most effective and should be adopted at all their mills and plants, thus insuring the most approved safeguards and familiarizing the superintendents, foremen and men with their use.

The Experience of Others.—We are here in the interest of the industrialist, the workman and the public, because these questions of safety and sanitation affect every man, woman and child in the United States. In this movement for a safer America we should all work together. The Museum proposes to benefit by the experience of others in collecting the best appliances and devices for making our life and labor safe.

A Life-Saving Fund.—To build and equip this life-saving station a fund of five million dollars must be raised. This is a comparatively small sum for a great industrial country like America, where the need is the greatest.

You are all invited to co-operate in this great movement by your subscriptions. If you cannot give much, give little, but give something. There are many who should give largely, because of the direct benefit which they will receive; others out of the largeness and generosity of their hearts.

This fund must be pledged before the Museum can be established. The men associated with this movement are a guarantee for the wisest use of the money intrusted to them, and this lecture campaign is undertaken to raise this fund and to gain your help, as it is impossible for us to do it alone. It is a movement for which you must work personally. It is a moral obligation which you owe to yourselves and to your country, that you should no longer be satisfied with the present conditions, with their unnecessary perils to life and limb, but you, as a patriotic American, should do all in your power to put America in the foremost rank among nations in the consideration and preservation of the lives of her people.

Business Men Will Oppose, Unless.—Germany, the great pioneer for workmen's compensation, was followed by Austria, Italy, France, Belgium, Hungary, Norway, Sweden, Denmark, Finland and Holland. Our country is the only civilized nation that has not changed the system of relegating the injured workman to a mere cause of action, to the duty of compensation in all cases whether there be negligence, contributary negligence or not.

The business men of this country will oppose an arbitrary law requiring them to make compensation, unless, at the same time, with the introduction of this change, they can be assured that a disinterested organization, like the Museum, is devoting a high-class, well-organized effort to ascertain, develop and exhibit every device for safety which can be devised by human ingenuity. At present the criticism to the general effect that it is cheaper to kill and maim employees than to protect them is in the main true. The reason for the existence of that condition, however, is not so much a general wanton disregard of human life as it is a general lack of knowledge, and the opportunity for gaining it, of devices and schemes for safety.

No Exploitation of Safety.—There is absolutely no organization in this country which is devoting any energy to the exploitation of measures of safety. The object of the Museum is to fill this void, and its organization is a part of a large change, of which the relief of the courts by the adoption of the European Compensation Acts is another part.

An act was passed at the last session of the New York Legislature for an inquiry as to the European compensation laws already adopted appointing a Commission on Causes of Industrial Accidents. You will see that we are on the threshold of a great change, and I believe that the most important contribution to that movement is the formation of the Museum of Safety.

[NOTE.—An elaborate collection of lantern photographs depicting both specific devices for the prevention of accidents and improved conditions resulting from systematic effort to better the condition of the factory operation were presented in the course of the lecture which most materially emphasized the merits of the speaker's plea for co-operation in establishing a permanent Museum of Safety and Sanitation.]

LEAD IN 1908.

REPORT ON SMELTER PRODUCTION.

The Geological Survey's report on the production of lead in 1908, prepared by C. E. Siebenthal, shows that 396,433 short tons was produced from foreign and domestic ores and base bullion during the year, or 17,756 tons less than in 1907, when the total product was 414,189 tons.

LOSSES AND GAINS BY STATES.

Missouri, the leading producer, showed an increase in the quantity of lead mined during the year as compared with that mined in 1907. The three States next in rank—Idaho, Utah, and Colorado—made largely reduced production. Of the smaller producers Wisconsin, Nevada, Montana, Kansas, and Oklahoma made gains in output.

PRICES.

The year 1908 opened with lead at 3.60 cents a pound, but the price steadily advanced until August, when it reached 4.625 cents a pound, and then declined steadily to 4.15 cents, the price at the close of the year. The price of lead during the eight years from 1901 to 1908 has ranged from 3.55 cents to 6 cents a pound.

UNITED STATES STILL LEADING PRODUCER.

Although the greatest loser in production in 1908 among the lead-mining countries of the world the United States nevertheless produced 27 per cent. of the world's output of lead.

The production of lead from foreign and domestic sources from 1825 to 1908, inclusive, was 8,635,236 short tons, of which 7,091,548 tons was produced from domestic ores and 1,543,688 tons from foreign ores and base bullion.

The report can be obtain from the Director of the Survey at Washington, D. C.

FRANKLIN INSTITUTE

(Proceedings of the stated meeting, held Wednesday evening, Dec. 15, 1909.)

HALL OF THE FRANKLIN INSTITUTE,

PHILADELPHIA, December 15, 1909.

President WALTON CLARK *in the Chair.*

Additions to membership since last meeting, 1.

A series of proposed amendments to the By-Laws was presented, signed by Messrs. E. H. Sanborn and James S. Rogers. The amendments were discussed by Messrs. Christie, Sanborn, and Colvin. On motion duly seconded it was directed that the amendments be voted upon by letter ballot.

The following nominations were made for officers, managers, and members of the Committee on Science and the Arts to be voted for at the annual election January 19, 1910:

For *President* (to serve one year), Walton Clark.

For *Vice-President* (to serve three years), Henry Howson.

For *Treasurer* (to serve one year), Cyrus Borgner.

For *Auditor* (to serve three years), Samuel P. Sadtler.

For *Auditor* (to serve two years), John C. Trautwine, Jr.

For *Managers* (to serve three years); Edwin S. Balch, W. C. L. Eglin, Alfred C. Harrison, Chas. A. Hexamer, Alexander Krumbhaar, Chas. E. Ronaldson, E. H. Sanborn, Walter Wood.

For *Members of the Committee on Science and the Arts* (to serve three years): James Christie, G. H. Clamer, Richard Gilpin, Wm. O. Griggs, Chas. A. Hexamer, Henrik V. Loss, Luther D. Lovekin, Thos. C. McBride, J. Y. McConnell, E. S. Powers, J. W. Ridpath, L. F. Rondinella, Arthur J. Rowland, Thomas Spencer, Wm. H. Thorne, Walton Clark, Jr., W. B. Riegner.

The chairman appointed the following members to act as tellers and receive the votes for the election of officers as well as those relating to the proposed changes of the By-Laws of the Institute: W. N. Jennings, Dr. W. J. Williams, Richard L. Binder, J. Logan Fitts, Werner Kaufmann, Dr. E. Goldsmith, Wm. H. Thorne.

Major Franklin Philips of Newark, New Jersey, was then introduced and presented his communication on the high-power rifle and its ammunition as instruments of precision. The speaker reviewed the history of the weapon, especially its most recent developments, and exhibited illustrations of the mechanism of the various parts of rifles, the forms of bullets, the sights, and other details. The lecturer closed with a reference to shooting matches and marksmanship.

On motion duly seconded a vote of thanks was tendered the speaker for his address. Adjourned.

JAMES CHRISTIE,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS

(*Abstract from proceedings of the stated meeting held Wednesday, December* 1, 1909.)

HALL OF THE FRANKLIN INSTITUTE,

PHILADELPHIA, December 1, 1909.

MR. J. Y. MCCONNELL *in the Chair.*

The following reports were presented for final action:

(No. 2450.) Brownstein's Boring and Reaming Tool—Benjamin Brownstein, Ansonia, Conn. (Report made advisory and adopted.)

(No. 2456.) Giles's Method of Briquetting Coal—Wm. F. Giles, Chester, Pa. (Report made advisory and adopted.)

The following reports passed first reading:

(No. 2464.) Rushton Trailing Truck for Locomotives.

(No. 2465.) Reese Dirigible Balloon. (Referred to subcommittee for reconsideration of award.)

(No. 2468.) Rushton Throttle for Locomotives. (Made advisory and adopted.)

C.

SECTIONS

(Abstracts of Proceedings of Stated Meetings.)

Mechanical and Engineering Section.—Stated meeting held Thursday, December 2, 1909. In the absence of the Chairman, Dr. E. Goldsmith presided. Present, 60 members and visitors.

The paper of the evening was presented by Mr. Wilber R. Kimball, President of the Aerial Development Company, and Secretary of the Aeronautic Society of New York, on "Flying—the New Art." The speaker reviewed and illustrated at length the development of the art of flying, particularly referring to its present condition and probable future.

JAMES CHRISTIE,
Secretary pro tem.

Photographic and Microscopic Section.—Stated meeting, held Thursday, December 9, 1909, 8 P.M. Dr. Henry Leffmann, President of the Section, in the chair. J. W. Ridpath, Secretary of the meeting. Present, 99 members and visitors.

Upon motion, the reading of minutes was dispensed with, and the Chairman introduced Prof. Robert W. Wood, of Johns Hopkins University, Baltimore, Md.

Professor Wood delivered an instructive and interesting lecture upon the "Infra-red and Ultra-violet Rays," describing in detail a number of original observations and experiments, particularly in photographing the moon. The lecture was illustrated by many lantern slides, contrasting views taken by the visible rays with the same taken by the invisible red or violet rays.

Upon motion the thanks of the Section were extended to the speaker.

J. W. RIDPATH,
Secretary.

Mining and Metallurgical Section.—Stated meeting held Thursday, December 16, 1909. Dr. Goldsmith presided in the absence of the Chairman. Present, 25 members and visitors.

After the reading of the minutes, the Chairman introduced Mr. Hiram W. Hixon of Philadelphia, who presented a paper entitled "A Comparison of Copper and Lead Smelting." The speaker illustrated the subject with lantern slides. At the close of the meeting a vote of thanks was tendered the speaker for his interesting paper. Adjourned.

JAMES CHRISTIE,
Secretary pro tem.

BOOK NOTICES

DIRECT AND ALTERNATING CURRENT TESTING. By Frederick Bedell, Ph.D., Professor of Applied Electricity in Cornell University, assisted by Clarence A. Pierce, Ph.D. 265 pages 9 x 6 inches with diagrams in the text. Price $2.00 net. D. Van Nostrand, New York, 1909.

The art of preparing efficient manuals of instruction has perceptibly advanced in recent years. Where formerly instruction in the theory and methods of conducting electrical tests could only be obtained by courses in technical schools, it is now possible to find in print skilfully planned presentations of the ground covered drawn from the gradually accumulated fund of data resulting from experience in teaching electrical practice.

Dr. Bedell's book is a work of this sort. He has selected from his collection of notes on electrical testing covering a period of many years those topics and methods of presentation that by actual trial and a process of evolution and refinement have yielded the best results technically and pedagogically. The aim has been to present representative topics in such a manner as to stimulate initiative and originality rather than to formulate a code of standardized forms and methods adopted to the needs of the modern "mental mechanic" who is now too frequently mistaken for an engineer worthy of the name.

L. E. P.

THE STORY OF THE COMETS, SIMPLY TOLD, FOR GENERAL READERS. By George F. Chambers, F.R.A.S. of the Inner Temple, Barrister at Law. XIII + 256 pages, 9 x 6 inches, 106 illustrations, cloth. Price 6 shillings, net. Clarendon Press, Oxford, 1909.

Unusual astronomical phenomena, particularly those of a spectacular nature, can scarcely fail to appeal to the popular mind. The widespread interest developed with the announcement of the expected reappearance of Halley's Comet, last seen in 1835—36, makes the issue at this time of a treatise on the subject for the purpose of enlightening the general reader most opportune. Those who would learn about comets, their constitution, their movements, their relation to other occupants of the firmament as well as matters of history and sentiment relating to them, may expect to be fully satisfied by a perusal of this evidently painstaking work.

The book is profusely illustrated by excellent half-tones and line-diagrams. The "story" is told in a fluent style attractive to the general reader but, despite this, it bristles with a formidable array of foot-notes and references that will tempt a serious reader, inclined to astronomical questions, to pursue a careful study of this fascinating subject.

L. E. P.

QUANTITATIVE CHEMICAL ANALYSIS ADAPTED FOR USE IN THE LABORATORIES OF COLLEGES AND SCHOOLS. By Frank Clowes, D.Sc., Lond., Emeritus Professor of Chemistry in the University College, Nottingham, and J. Bernard Coleman, A.R.C.Sc., Dublin, Head of the Chemical Department in the South-Western Polytechnic, Chelsea, S. W. Eighth Edition, XXIV + 565 pages, 9 x 6 inches, 133 illustrations, cloth. Price $3.50. P. Blakiston's Son & Co., Phila., 1909.

Perhaps in no other branch of science is it more true than in chemistry that an adequate knowledge of the subject can only be attained through

familiarity gained by diligent practice in the many manipulations involved and carrying out processes by well accredited methods. That the authors have fulfilled this requirement is shown by the minute care with which the many details of the operations of quantitative work are described.

Its scope is comprehensive, covering the ground from fundamental operations through the entire range of topics embraced in quantitative analysis and the minute detail of treatment should remove many practical difficulties of the student and lighten the labors of the teacher.

That the work is now in its eighth edition testifies to its extensive usefulness.

L. E. P.

A MANUAL OF VOLUMETRIC ANALYSIS, TREATING ON THE SUBJECT OF INDICATORS, TEST-PAPERS, ALKALIMETRY, INCLUDING ASSAY OF DRUGS BY TITRATION, ACIDMETRY, ANALYSIS BY OXIDATION AND REDUCTION, IODOMETRY, DETERMINATIONS BY PRECIPITATION, AND BY COLOR DISPERSION. By Virgil Coblentz, Ph.D., Phar.M., F.C.S., Professor of Chemistry in the New York College of Pharmacy, and Anton Vorisek, Phar.D., Professor of Analytical Chemistry in the College of Pharmacy, Columbia University, in the City of New York. VIII + 234 pages, 9 x 6 inches, with 38 illustrations, cloth, second edition, completely reconstructed and enlarged. Price $1.75 net. P. Blakiston's Sons & Co., Phila., 1909.

The principles of volumetric analysis are here presented in harmony with modern theories, particular attention being devoted to the theory of ionization and its application to indicators and other chemical reactions, to the necessary precautions as to dilution, temperature and to the influence of disturbing elements. The importance of the preparation and accurate standardization of the reagent solutions is emphasized and throughout the work the necessary precautions to be observed in conducting an analysis are impressed upon the operator.

L. E. P.

THE ZONAL-BELT HYPOTHESIS. A New Explanation of the Cause of the Ice Ages. By Joseph T. Wheeler. 401 pages, 9 x 5½ inches, cloth. Price $2.50 net. J. B. Lippincott Company.

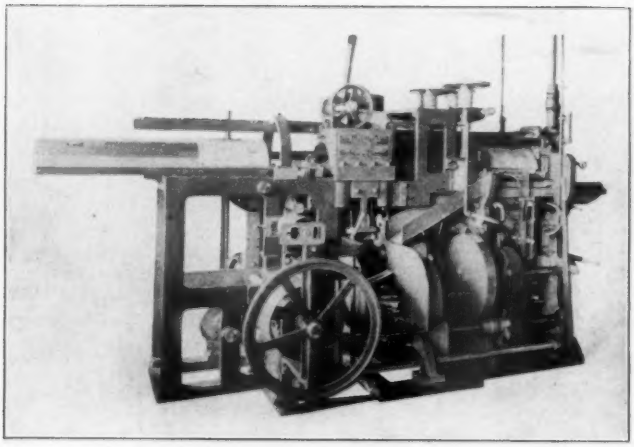
The purpose of this work is to show that our earth, up to a late period in its geological formation, was surrounded by rings like Saturn, and that these had an important influence in determining the climatic changes which marked various geological periods. The author has, in presenting his argument, been unsparing of labor in his search of evidence and data and the book contains an extensive array of references to support his hypothesis.

The work should prove of interest to those devoted to the investigation of cosmic problems.

L. E. P.

PRESS OF
J. B. LIPPINCOTT COMPANY
PHILADELPHIA

FIG. 1.



The Autoplate Machine—casts, finishes, cools, and delivers ready for the press, newspaper printing plates at the rate of from 4 to 8 a minute.